Natural Sciences and Engineering Research Council of Canada
Conseil de recherches en sciences naturelles et en génie du Canada

Ottawa, Canada
K1A 1H5

CANADA'S FUTURE REQUIREMENTS FOR HIGHLY QUALIFIED SCIENTISTS AND ENGINEERS

BESOINS FUTURS DU CANADA EN PERSONNEL SCIENTIFIQUE ET TECHNIQUE HAUTEMENT QUALIFIÉ

Papers presented at a seminar sponsored by the Natural Sciences and Engineering Research Council of Canada

Conférences présentées dans le cadre du séminaire parrainé par le Conseil de recherches en sciences naturelles et génie du Canada

Ottawa

May 3, 1989

Ottawa

Le 3 mai, 1989

Canada

90-00956/

PREFACE

For several years the Natural Sciences and Engineering Research Council has been concerned about the possibility of a future shortage of highly qualified scientists and engineers, those key people who will be essential for Canada's future success as an industrialized country. The Council's Five-Year Plans, published in 1979 and 1985, both drew attention to the impending problem and its recently published Strategic Plan "Ten Years to 2000" stresses the importance of taking action to ensure that Canada will have an adequate supply of research personnel in the coming decade.

Canada's situation is not unique. Virtually all member countries of the Organization for Economic Cooperation and Development (OECD) share our preoccupation and many are taking steps to try to head off the anticipated imbalance between the supply of and demand for highly qualified personnel.

In view of its perception of the importance of this issue, NSERC decided to share its concerns with a group of knowledgeable people from across the country, drawn from the business, academic and government sectors. An all-day meeting held in Ottawa on May 3, 1989, provided an opportunity for representatives of the three sectors to exchange views and explore possible solutions. Is NSERC justifiably concerned? If so, what should it and other organizations do to alleviate the problem? These were some of the questions discussed.

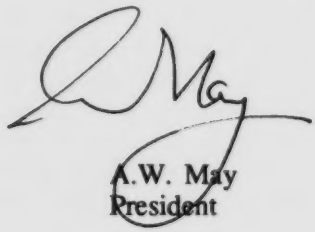
I think it is fair to say that there was widespread support amongst the participants in this meeting for the view that, barring unforeseen events such as a major recession, there is a real danger that our demand for highly qualified engineers and scientists will outstrip our supply during the 1990's and into the twenty-first century. Of course, the situation will not be identical in all fields or disciplines and there may even be surpluses in certain areas. But overall, demographic facts and business trends strongly suggest that many employers, in all sectors, will experience difficulties in filling vacancies that require education beyond the bachelor's level in science or engineering.

As to what action should be taken to minimize the problem, it appears that there is no single easy remedy. Certainly NSERC will give high priority to its various scholarships and fellowships programs in order to increase the number of Canadians with postgraduate degrees. There is a clear need to encourage more women to enter engineering and science careers. Many organizations, including NSERC, are trying to do something about that challenge. The problem of inadequate science education and the need for better counselling in the schools were mentioned frequently.

It is clear that no single organization can be the agent that is instrumental in bringing about a substantial increase in the supply of scientists and engineers. The commitment and cooperation of many organizations, in all sectors and throughout the country, will be required. It is for this reason that NSERC has decided to reprint the papers that were presented at the May meeting and to share them with a much wider audience. The papers are reprinted here exactly as given to us by the authors and no attempt has been made to edit them in order to achieve a uniform style or format. It is our hope that you will find the papers interesting and thought-provoking and that they will cause you to reflect upon the issue of Canada's need for more highly qualified engineers and scientists. Perhaps you will be stimulated to propose some actions within your own organization, professional society, or province. In any event, we would be pleased to receive any comments or suggestions that you feel would be of interest to NSERC.

In concluding this introduction, I think it is very appropriate to give two brief quotations from the remarks made by the Honourable William Winegard, Minister of State (Science and Technology), when he opened our meeting:

> "Knowledge is the single commodity that is going to matter and if we haven't got a good spectrum of people able to work in science and technology, this country is going nowhere."
>
> "I cannot recall a time when Canada has so urgently needed the talents of our scientists and our engineers as we do now."



A.W. May
President

PRÉFACE

L'éventuelle pénurie de scientifiques et d'ingénieurs hautement qualifiés risque d'avoir des conséquences graves pour l'avenir du Canada à titre de pays industrialisé. C'est là l'une des grandes préoccupations du Conseil de recherches en sciences naturelles et en génie (CRSNG), qui publiait récemment un document stratégique intitulé «Dans dix ans, l'an 2000». Dans ce document, il énonce sa stratégie au cours de la prochaine décennie pour concentrer ses efforts sur des programmes visant à assurer au Canada l'existence d'un bassin de personnel scientifique suffisant pour répondre aux besoins de la société. Les deux plans quinquennaux du CRSNG publiés en 1979 et en 1985 avaient d'ailleurs déjà attiré l'attention sur l'imminence d'une telle pénurie.

Le Canada n'est pas le seul pays industrialisé touché par ce problème. Presque tous les pays membres de l'Organisation de coopération et de développement économiques (OCDÉ) connaissent une situation similaire et partagent la préoccupation du Canada à cet égard. Plusieurs d'entre eux ont d'ailleurs pris des mesures visant à contrer le déséquilibre prévu entre l'offre et la demande en personnel de recherche.

Compte tenu de l'importance qu'il attache à cette question, le CRSNG tenait à Ottawa, le 3 mai 1989, un séminaire d'une journée afin de discuter des répercussions d'une telle pénurie sur l'économie canadienne et d'explorer des solutions possibles au problème. Ce séminaire, qui regroupait des experts canadiens, a permis de tenir une discussion ouverte, d'obtenir des conseils et de favoriser des échanges de vues entre des représentants du milieu des affaires, des universités et des gouvernements. Le CRSNG a-t-il raison de s'inquiéter? Quelles mesures devrait-il prendre? Comment assurer la collaboration d'autres organismes visés par le problème? Voilà autant de questions débattues par les participants.

La majeure partie des participants se sont entendus pour dire qu'à moins d'une récession grave ou d'autres impondérables du même genre, la demande de scientifiques et d'ingénieurs devrait largement dépasser l'offre au cours des années 90 et dans les années subséquentes. Évidemment, la situation ne sera pas identique dans tous les domaines ou toutes les disciplines; certains domaines pourraient même connaître un surplus de personnel scientifique. Les données démographiques et les tendances économiques actuelles permettent déjà de prévoir les difficultés qu'auront de nombreux employeurs dans tous les secteurs lorsqu'il s'agira de pourvoir des postes exigeant une formation aux cycles supérieurs en sciences naturelles et en génie.

Cette question suscite un intérêt croissant; cependant il est bien évident qu'il n'existe pas de solution miracle pour minimiser les effets du problème. Le CRSNG entend toutefois accorder une priorité élevée à ses divers programmes de bourses visant à accroître le nombre de Canadiens titulaires de diplômes d'études supérieures. Le faible taux d'engagement des femmes dans des carrières en sciences et en génie est également un important sujet de préoccupation. À cet égard, un certain nombre d'organismes, dont le CRSNG, cherchent des solutions. Par ailleurs, les participants du séminaire ont identifié comme éléments du problème l'enseignement inadéquat des sciences dans les écoles et la nécessité d'offrir de meilleurs services d'orientation vers les carrières scientifiques.

Il est clair qu'un organisme seul ne peut augmenter considérablement l'apport de scientifiques et d'ingénieurs. L'engagement et la collaboration de nombreux organismes de toutes les régions du pays sont essentiels pour atteindre ce but. Nous avons donc décidé de diffuser les documents présentés dans le cadre de ce séminaire en vue de rejoindre le plus vaste auditoire possible et de le sensibiliser à l'urgence de la question. Les articles sont reproduits intégralement. J'espère qu'ils sauront vous intéresser et qu'ils seront source d'inspiration ou qu'ils serviront à lancer la discussion sur les besoins futurs du Canada en main-d'oeuvre scientifique hautement qualifiée. En vous fondant sur l'expérience du CRSNG, vous voudrez peut-être proposer des mesures à prendre au sein de votre societé, association ou organisme gouvernemental; nous apprécierions en être informés et recevoir vos commentaires sur le sujet.

En guise de conclusion, je me contenterai de citer deux extraits de l'allocution d'ouverture prononcée par l'honorable William Winegard, ministre d'État (Sciences et Technologie) qui, à mon avis, cristallisent le problème et en illustrent les enjeux pour le Canada :

> «Le savoir est la seule ressource qui aura de l'importance, et, à moins d'assurer l'existence d'un bassin de main d'oeuvre hautement qualifiée en sciences et en génie, un avenir difficile nous attend.»

> «À mon avis, jamais le Canada n'a eu autant besoin des compétences de ses scientifiques et de ses ingénieurs.»

A.W. May
Président

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Natural Sciences and Engineering Research Council of Canada
Conseil de recherches en sciences naturelles et en génie du Canada

Canada's Future Requirements for Highly Qualified Scientists and Engineers

A discussion by industry, government and academic representatives of the challenges and demands that lie ahead

Wednesday, May 3, 1989

Canada

PROGRAM

09:00 **Opening**
Arthur May, President, Natural Sciences and Engineering Research Council of Canada

Introductory Remarks
The Honourable William Winegard, Minister of State (Science and Technology)

SESSION I

Under the chairmanship of Mary Spencer, University Professor, Department of Plant Science, University of Alberta

09:15 **Research and Development and the Canadian Economy in the 90's.**
Judith Maxwell, Chairman, Economic Council of Canada

10:00 **Issues and Problems Relating to Highly Qualified Personnel in the United States**
Alan Fechter, Executive Director, Office of Scientific and Engineering Personnel, National Research Council, Washington

11:00 **Break**

11:15 **Requirements for Highly Qualified Scientists and Engineers in the Federal Government**
Huguette Labelle, Chairman, Public Service Commission of Canada

12:00 **Luncheon**
Drawing Room
Address by Harry G. Rogers, Deputy Minister, Department of Industry, Science and Technology

All sessions take place in the Adam Room of the Chateau Laurier, 1 Rideau Street, Ottawa, Ontario (613) 232-6411

SESSION II

Under the chairmanship of Philip Lapp, President, Philip A. Lapp Ltd., Past President, Canadian Council of Professional Engineers

13:30 **Highly Qualified Personnel in OECD Countries**
Gilles Julien, Executive Vice-President, Natural Sciences and Engineering Research Council of Canada

14:00 **Requirements for Highly Qualified Personnel by Canada's High Technology Sector**
Tom Hennebury, Vice-President, Human Resources and Administration, Bell Northern Research

14:45 **Break**

15:00 **The Capacity of Canada's Universities to Educate Highly Qualified Scientists and Engineers**
Arnold Naimark, President, University of Manitoba

15:45 **The Future Supply of Highly Qualified Engineers and Scientists and the Role of NSERC**
Robert Kavanagh, Director-General, Scholarships and International Programs Natural Sciences and Engineering Research Council of Canada

16:30 **Summary and Concluding Remarks**
Claudette MacKay-Lassonde, Director, Educational Relations, Northern Telecom Canada Ltd., and Chairman, Canadian Engineering Manpower Board

Besoins futurs du Canada en personnel scientifique et technique hautement qualifié

Rencontre de représentants des milieux industriel, gouvernemental et universitaire pour discuter des défis et des besoins à venir

Le mercredi 3 mai 1989

Canada

- IX -

PROGRAMME

9 h **Mots de bienvenue**
Arthur May, président, Conseil de recherches en sciences naturelles et en génie du Canada

Allocution d'ouverture
L'honorable William Winegard, ministre d'État (Sciences et Technologie)

SÉANCE I

Sous la présidence de Mary Spencer, professeur au département de phytotechnie de l'Université de l'Alberta

9 h 15 **La recherche et développement et l'économie canadienne des années 90**
Judith Maxwell, présidente, Conseil économique du Canada

10 h **Questions et problèmes de main-d'oeuvre hautement qualifiée aux États-Unis**
Alan Fechter, Executive Director, Office of Scientific and Engineering Personnel, National Research Council, Washington

11 h **Pause**

11 h 15 **Besoins de scientifiques et d'ingénieurs hautement qualifiés au gouvernement fédéral**
Huguette Labelle, présidente, Commission de la Fonction publique du Canada

12 h **Déjeuner**
Grand salon
Allocution par Harry G. Rogers, sous-ministre de l'Industrie, des Sciences et de la Technologie

Toutes les séances ont lieu dans le salon Adam, Château Laurier, 1, rue Rideau, Ottawa (Ontario) (613) 232-6111

SÉANCE II

Sous la présidence de Philip Lapp, président de Philip A. Lapp Ltd., et ancien président du Conseil canadien des ingénieurs

13 h 30 **La main-d'oeuvre hautement qualifiée dans les pays de l'OCDE**
Gilles Julien, vice-président exécutif, Conseil de recherches en sciences naturelles et en génie du Canada

14 h **Besoins de main-d'oeuvre hautement qualifiée dans le secteur de la haute technologie au Canada**
Tom Hennebury, vice-président des Ressources humaines et administration, Recherches Bell-Northern

14 h 45 **Pause**

15 h **La capacité des universités canadiennes à former des scientifiques et des ingénieurs hautement qualifiés**
Arnold Naimark, président, Université du Manitoba

15 h 45 **Les futurs scientifiques et ingénieurs hautement qualifiés et le rôle du CRSNG**
Robert Kavanagh, directeur général des Bourses et programmes internationaux, Conseil de recherches en sciences naturelles et en génie du Canada

16 h 30 **Résumé et mot de la fin**
Claudette MacKay-Lassonde, directrice aux Affaires pédagogiques, Northern Telecom Canada Ltée, et présidente du Bureau canadien de la main-d'oeuvre en génie

HIGHLY QUALIFIED PERSONNEL: A KEY TO SUCCESS IN GLOBAL COMPETITION

(Dr.) Keith Newton
Senior Research Director

Economic Council of Canada

June 1989

The purpose of this paper is to sketch some of the major trends and developments which constitute the backdrop for a more detailed discussion of Canada's needs for highly qualified personnel. The first important observation is that it is increasingly clear that human resources will be the key to Canada's survival in a fiercely competitive and technologically sophisticated global economy. Rapid adoption of the new technologies will, of course, be essential in such a world. But for the knowledge-based information economy the quality of the workforce will also be of paramount importance.

Trends and developments in the global economy may be observed with reference to a number of charts and graphs. First of all the potential forces of competition may be appreciated with reference to Chart 1, which shows the convergence in economic performance that has taken place in the last thirty-five years. In Chart 1, Canada's situation shows a long-run trend towards convergence with the performance of the United States, although in recent years that performance as measured by real GDP per capita has diverged again somewhat. What is clear is that some countries, most notably Japan, but other Southeast Asian countries like South Korea, Taiwan, and Singapore, have had quite spectacular rates of improvement in economic performance in the last decade, and are quickly closing the gap with Canada and the United States.

In the midst of such global forces, observers increasingly question whether Canada can continue to survive by relying upon

traditional activities based on exploitation of natural resources. Can we, in other words, continue to be hewers of wood and drawers of water? Chart 2, for example, shows that in the last twenty-five years the commodity price index has been steadily downwards. (In fact, this downward trend is a long-run secular phenomenon that has been observed for at least the last half century.) What Canada will increasingly be required to do, therefore, is to concentrate on activities with a high knowledge and information content. In short, we will have to rely more on brains and less on brawn. And it is precisely when we concentrate on the upper end of the value-added scale that recent figures give us some cause for concern.

A glance at Chart 3, for example, reveals that in Canada technology-intensive industries' share of manufacturing value-added is lower than is the case for a number of major international competitors. What is disturbing, however, is not just the overall levels, but the fact that in the period between 1969 and 1985 Canada's improvement has been slight in comparison with her trading rivals. Our performance in terms of a number of science and technology criteria has been equally disturbing. Chart 4 ranks Canada among 8 other industrialized countries in terms of a number of measures of science and technology competitors. Clearly, Canada's ranking is low on most of these criteria.

Such considerations are important because of their implications for productivity and competitiveness. Chart 5 illustrates the so-called productivity gap amongst a number of major industrialized countries in the period from 1951 to 1987. Canada's position is depicted by the horizontal line, and the performance of the United States is shown by the heavy dark line in the upper part of the figure. After a long period of convergence between the performance of the United States and Canada, it appears that the U.S. has started to pull away again in the latter part of the 1980s. It can be seen that in the late seventies and early eighties other countries surpassed Canada's performance. This picture may be rounded out by looking at some additional indicators of international performance. Chart 6, for example, is based on a survey of the competitiveness of some 22 OECD countries. Once again it is apparent that, particularly with respect to human resource development, Canada has a long way to go.

This emphasis on human resource development continues to surface in empirical studies of productivity, competitiveness and technological change. For example, our own research at the Economic Council of Canada suggests that innovation is as much a question of people management and workplace design as it is a question of installing new machinery and equipment. Chart 7 shows some of the various kinds of organizational innovations that can help to create the climate within which new technologies and people can be brought

together effectively. An important conclusion of the Council's research was that the process of technological diffusion requires adjustment on the part of organizations and on the part of the workforce. For example, one effect of the new technologies, illustrated in
Chart 8, is a transformation of the occupational structure. The Council's survey of almost 1,000 establishments across Canada in a variety of industries in the private sector shows a marked difference in the occupational structure of the innovating firms when compared to the non-innovating firms. Specifically, it is clear that in innovating firms the proportion of workers in blue-collar occupations shrinks considerably. Such a transformation in the occupational structure clearly has important implications for the skill content of jobs and, therefore, for the education and training that is necessary to prepare workers for the emerging jobs of the future.

Recent projections from the Canadian Occupational Projections Service of the Department of Employment indicate that the educational attainment levels for the new jobs which are expected to be created between now and the end of the century will increase substantially. It can be seen from Chart 9, for example, that many of the occupations that are expected to contribute large numbers of new jobs in the period require 12 years of education or more. This impression of rising skill requirements is clearly confirmed with

reference to Chart 10, which compares the educational attainment levels of the workforce at the time of the 1986 Census with the educational attainment levels of the new jobs which are expected to be created between now and the end of the century. What is striking about this chart is that almost half of the expected new jobs to the year 2000 will require 17 or more years of schooling. Patently, then, highly qualified personnel are at a premium.

Such figures have important implications for the quality of the Canadian education system. How then do we compare with other countries? At first glance the situation is not too bad. Examination of Chart 11, for example, indicates that Canada ranks second only to Sweden in terms of educational expenditure as a percentage of GDP. Moreover, if one looks at postsecondary enrolment as a percentage of the population aged 20 to 24, once again the international comparisons are relatively reassuring. In this case Canada ranks second to the United States. However, there appears to be little room for real complacency.

Paradoxically, at a time when the average educational attainment of the Canadian workforce is higher than ever before, we also have a drop-out problem from Canadian high schools of major proportions and the shocking evidence of a 25 per cent illiteracy rate. Moreover, when we turn to Canadian educational attainment in the fields of science and, particularly, mathematics, the picture is far

from reassuring. Results of the International Mathematics Study for students in their final secondary year, for example, are shown in Chart 13. Canada's performance, as illustrated by the provinces of British Columbia and Ontario, lags behind that of England and Wales, of Sweden and, most markedly, behind the performances of Hong Kong and Japan.

The emphasis we have placed on human resource development is most particularly reinforced by certain salient demographic developments. The two final charts (numbers 14 and 15) vividly illustrate the nature of these constraints. First, one can see in Chart 14 the way in which the youth-share of the labour force is expected to decline markedly in the period between now and the end of the century. It is to this segment of the labour force that we typically look for the latest knowledge, training and techniques. These are the people on whom we rely heavily for creativity and new ideas. Combining this situation with the more general picture of labour force growth rates to the end of the century as depicted in Chart 15, it is clear that this country faces a major challenge of human resource management.

What these demographic constraints strongly suggest is that our existing human resources will have to be utilized more efficiently and more innovatively than ever before. Learning will have to become virtually continuous, and educational institutions will

therefore be required to go through a major process of adjustment to meet the emerging needs of the workforce of the future. Much closer links between the education system and the corporate sector will become a necessity, and the relative roles and responsibilities of the public and private sectors will come under close scrutiny.

To sum up, Canada's ability to survive and prosper in the global economy will depend no less upon human resources than upon technological sophistication. Science and technology, supported by a highly qualified workforce, are the keys to productivity and competititiveness in the long run.

CHART 1

Convergence towards the United States

Index of real GDP per capita, selected countries, 1950-85

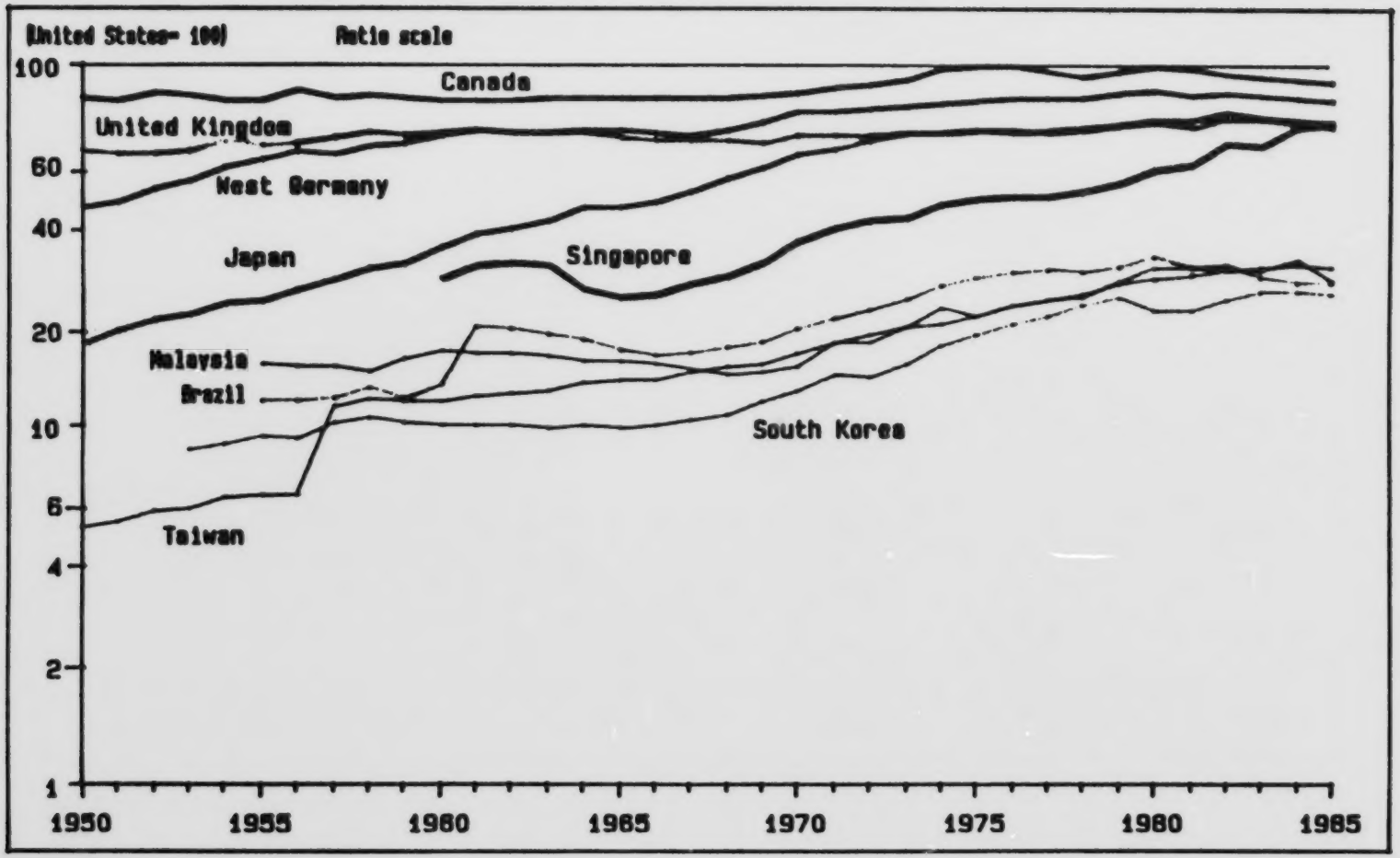
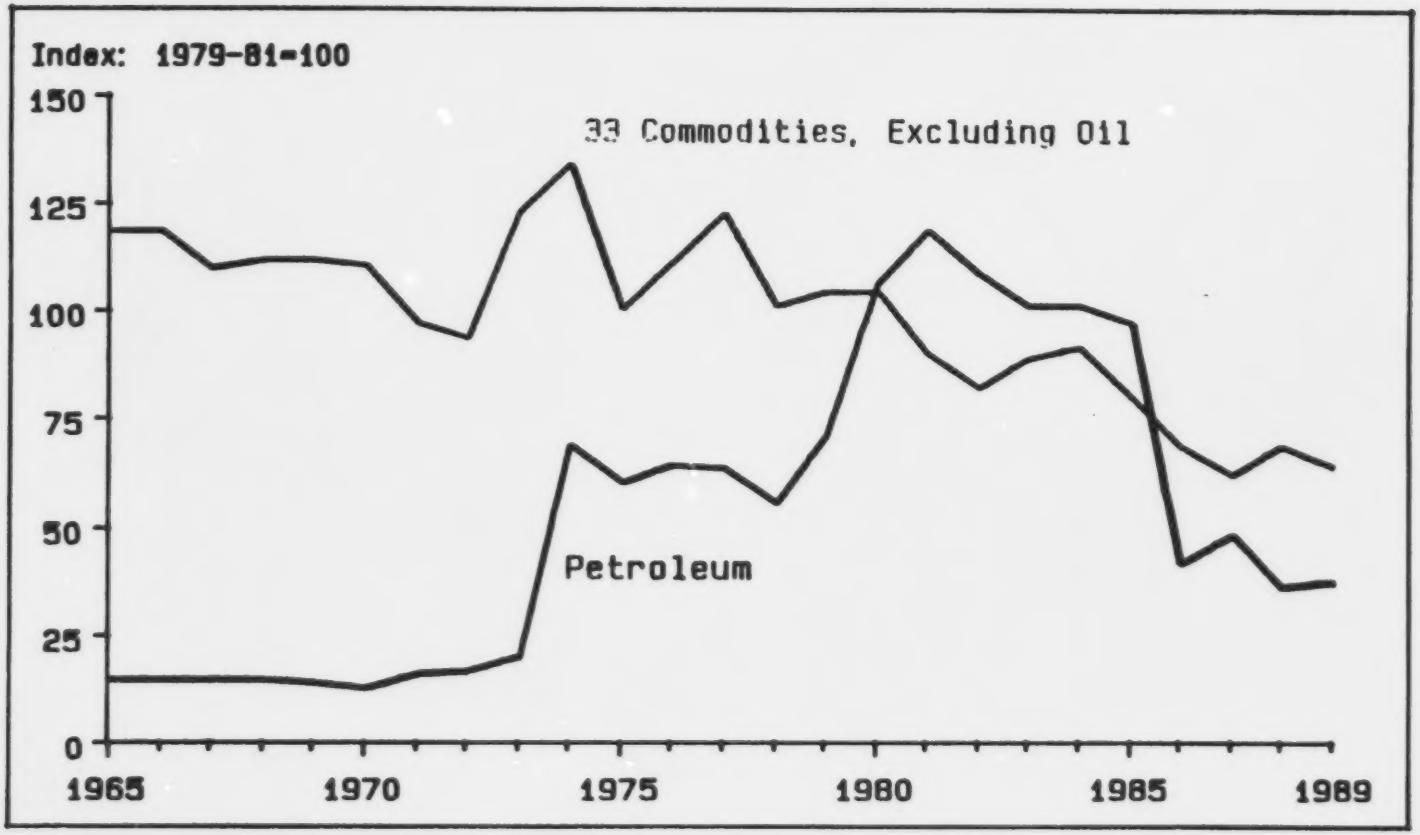


CHART 2

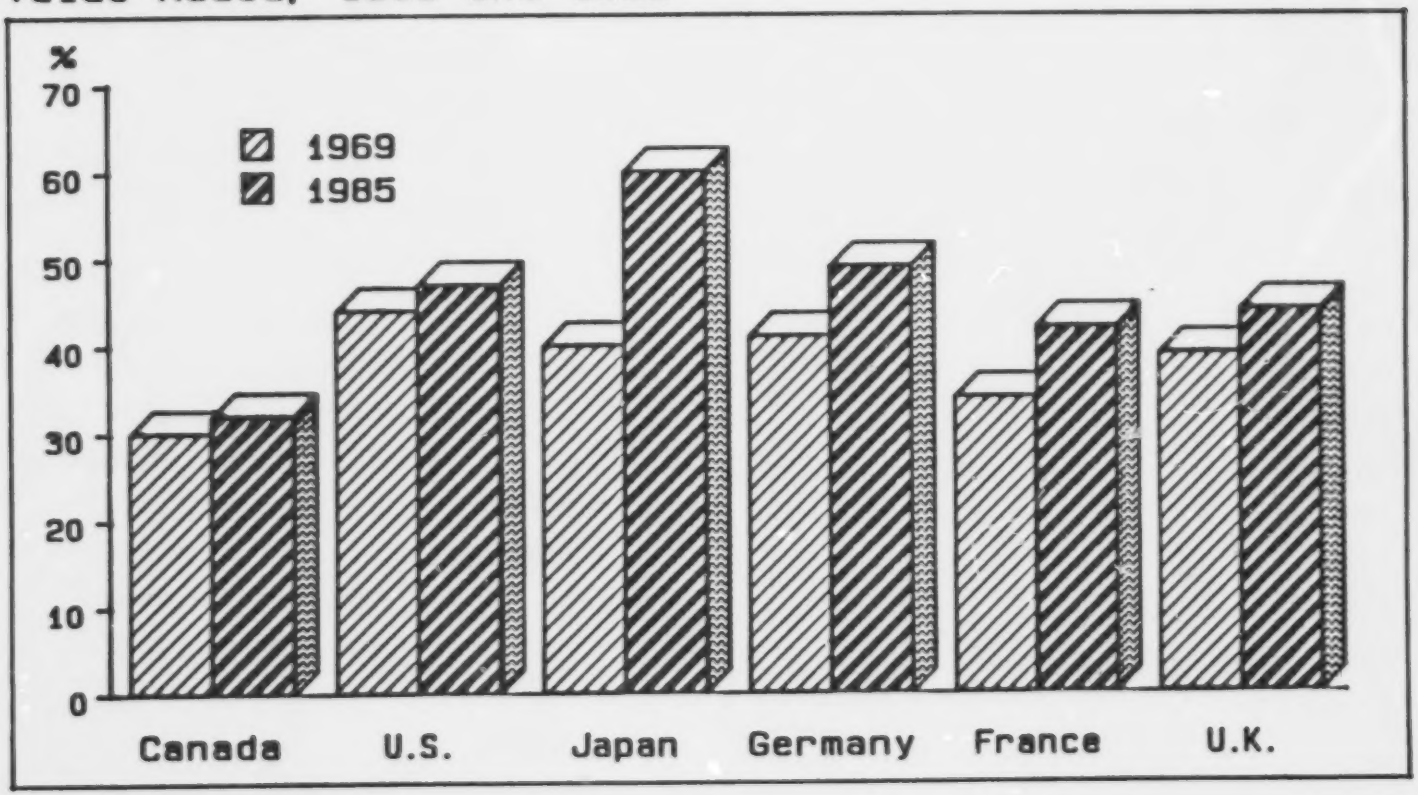
"Real" Commodity Prices, 1965-1989



Deflated by manufacturing unit value index
Source: World Bank.

CHART 3

Technology Intensive Industries' Share of Manufacturing Value Added, 1969 and 1985



Source: National Planning Association, 1988

CHART 4

Canada's Science & Technology Performance

Measure of S&T Competitiveness	Canada's Rank Among Eight Comparable Countries*
Gross R&D expenditures as % of GDP	Lowest
Industry-funded R&D/GDP	Lowest
Government-funded R&D/GDP	2nd Lowest
Government-performed R&D/GDP	Middle
Higher education R&D/GDP	2nd Lowest
Domestic patents granted per 100,000inhabitants	2nd Lowest
International patents granted (by population)	Lowest
Advanced degrees awarded (by population)	Middle
Scientists and engineers in labour force (by population)	Lowest
Number of technology-intensive industries with positive trade balance	Lowest

* Canada, U.S., Germany, France, Sweden, U.K., Netherlands, Japan.

Source: See footnote, Table 1.

CHART 5

Canadian Manufacturing Labour Productivity Level (output per hour) Relative to the Other G-7 Countries (Canada= 100)

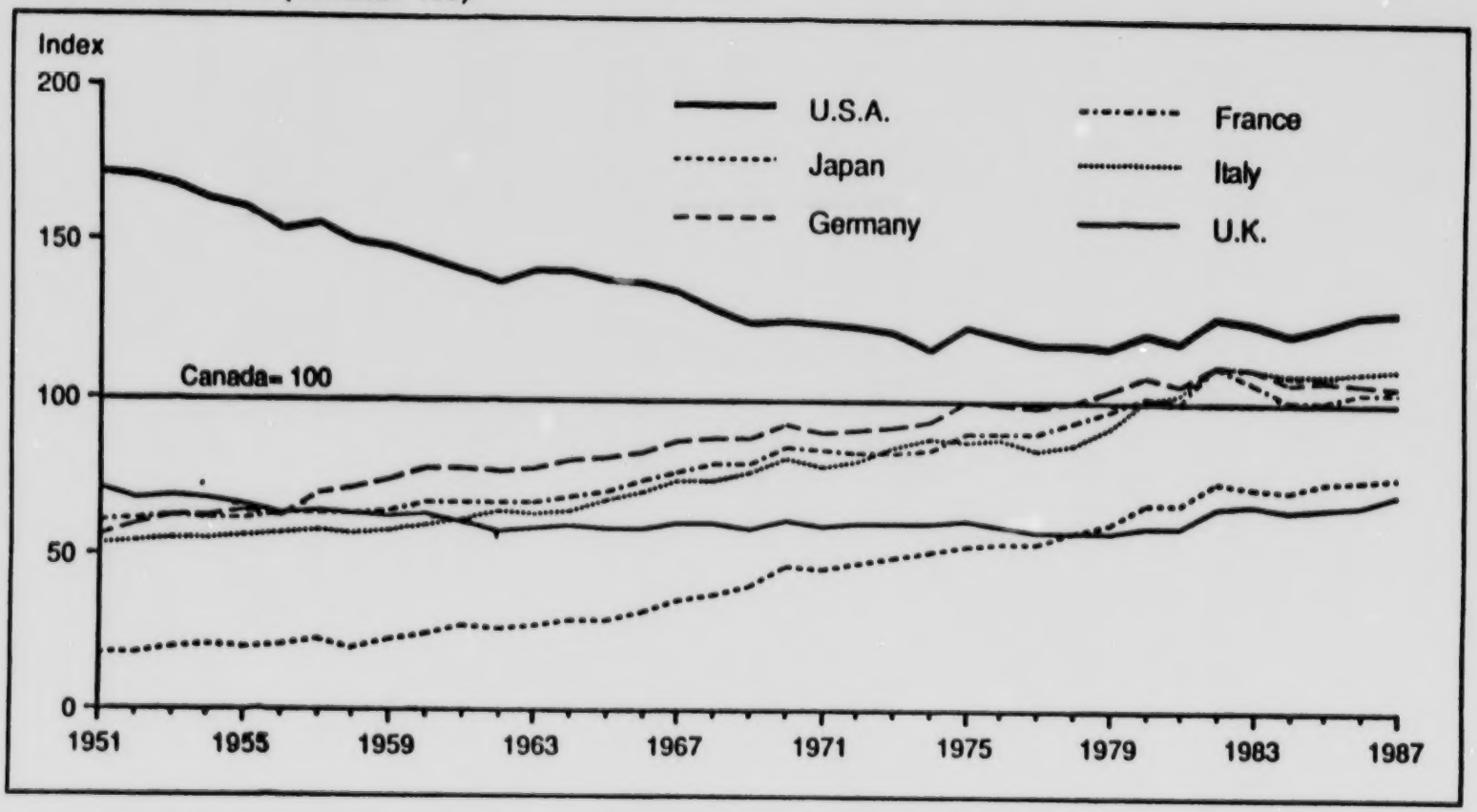


CHART 6

INTERNATIONAL COMPETITIVENESS SURVEY

CANADA'S RANK OUT OF 22 OECD COUNTRIES, SELECTED INDICATORS

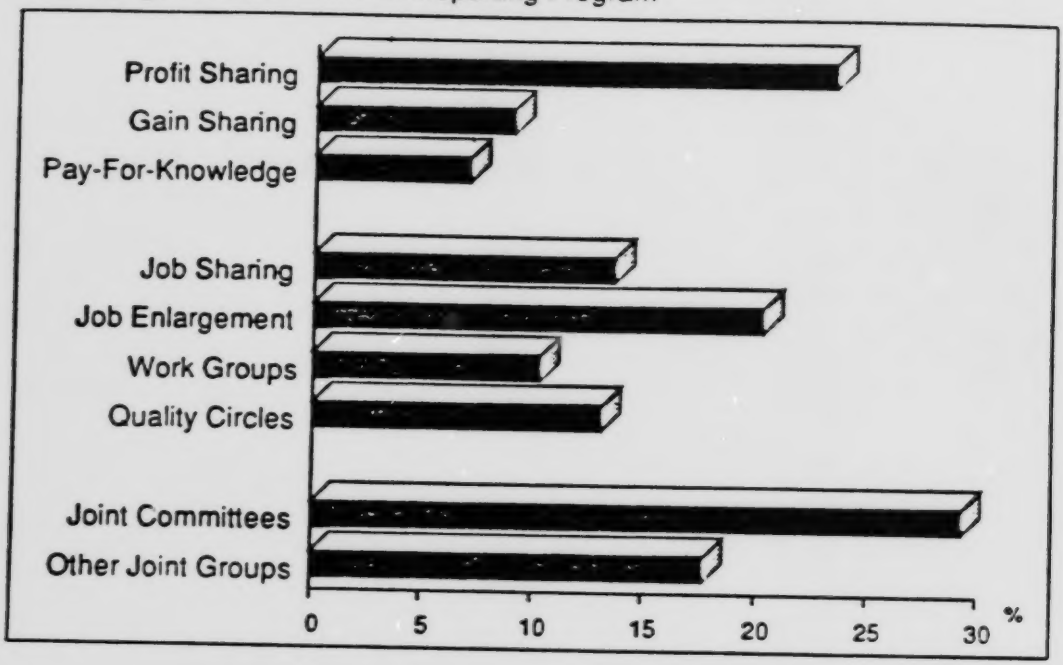
Indicators	Rank
Extent to which educational and training institutions adequately prepare executives for needs of business	7
Computer literacy of top management	8
Managerial drive, responsibility and entrepreneurship	10
Adequacy of vocational training for requirements of a competitive economy	13
Availability of skilled labour	15

Source: European Management Forum, 1986.

CHART 7

Organizational Innovations

Percentage of Establishments Reporting Program



Source Gordon Betcherman and Kathryn McMullen, Working with Technology: A Survey of Automation in Canada (Ottawa: Minister of Supply and Services, 1986).

Occupational Structure of Innovating and Non-Innovating Establishments, Canada, 1985

Source Economic Council of Canada, "Working with Technology" Survey, 1985.

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CHART 9

The Changing Occupational Structure, 1986-2000

(New Jobs 1986-2000)

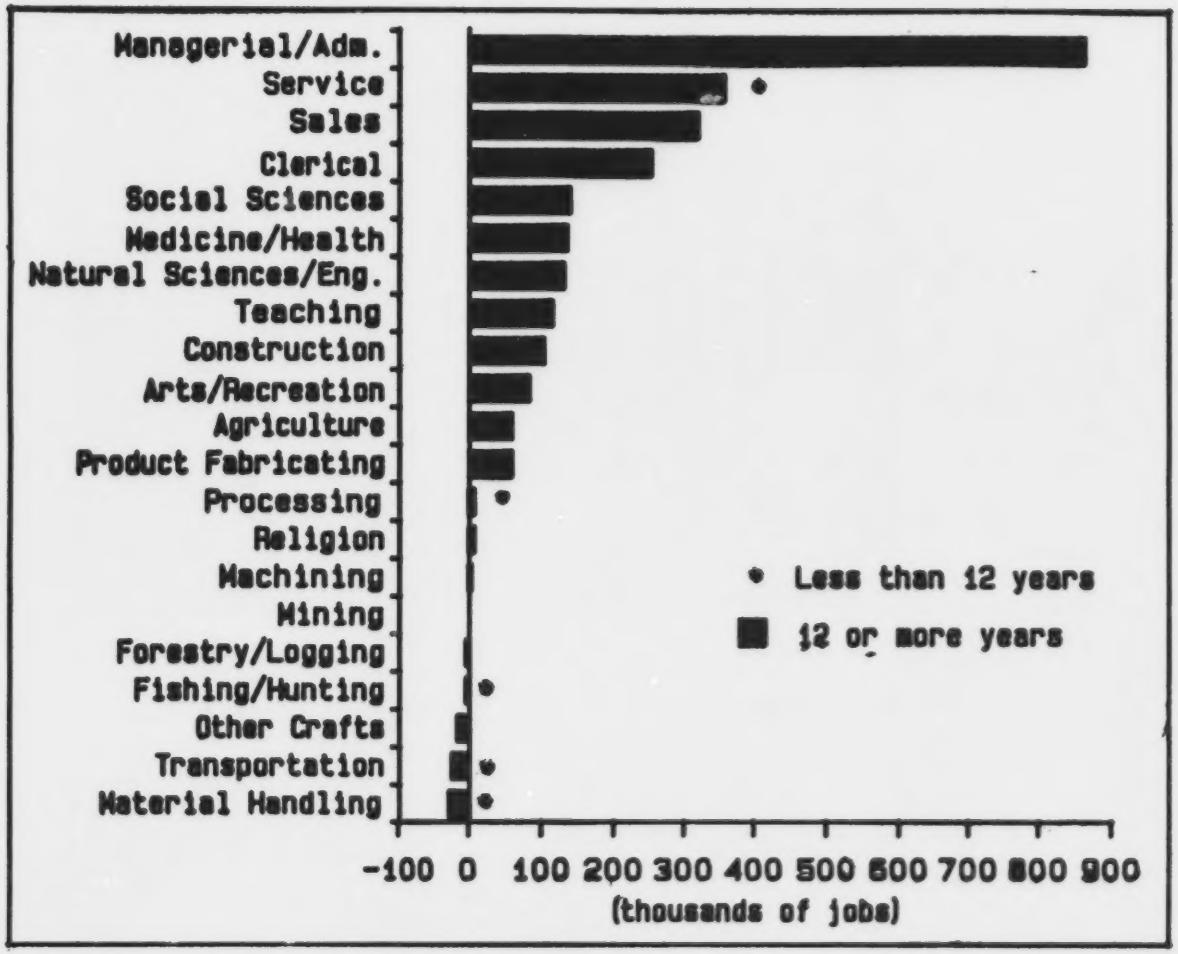

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CHART 10

Rising Skill Requirements

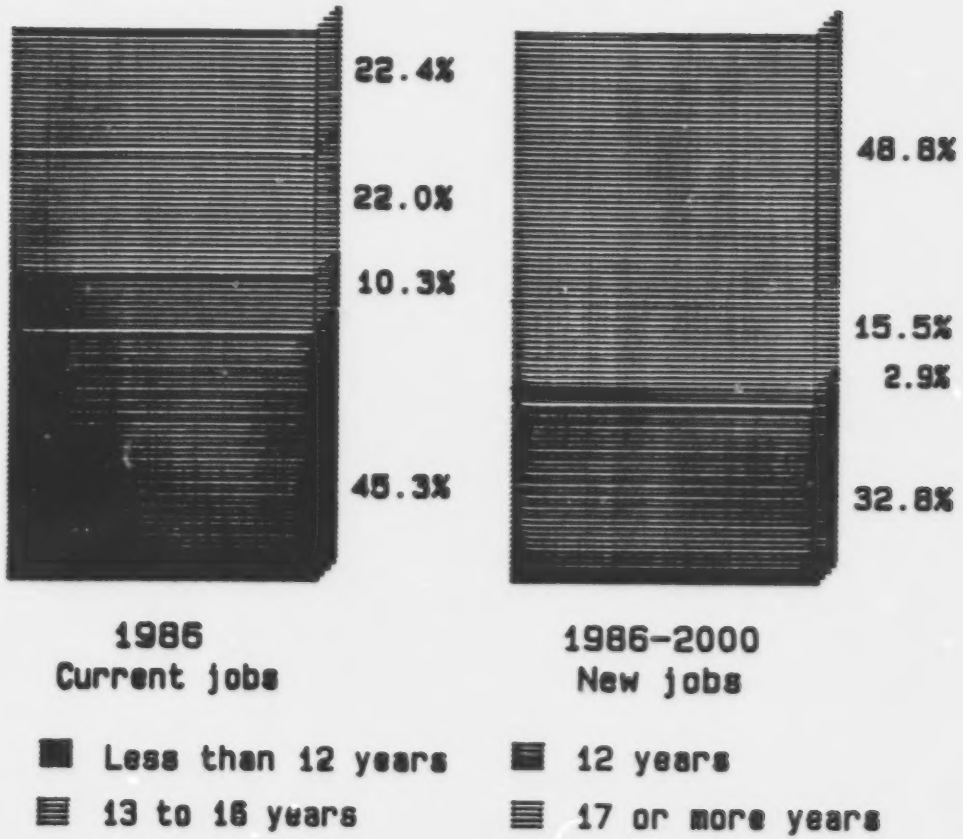

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CHART 11

Educational Expenditure as a Percentage of GDP, 1985 or Most Recent Available Year

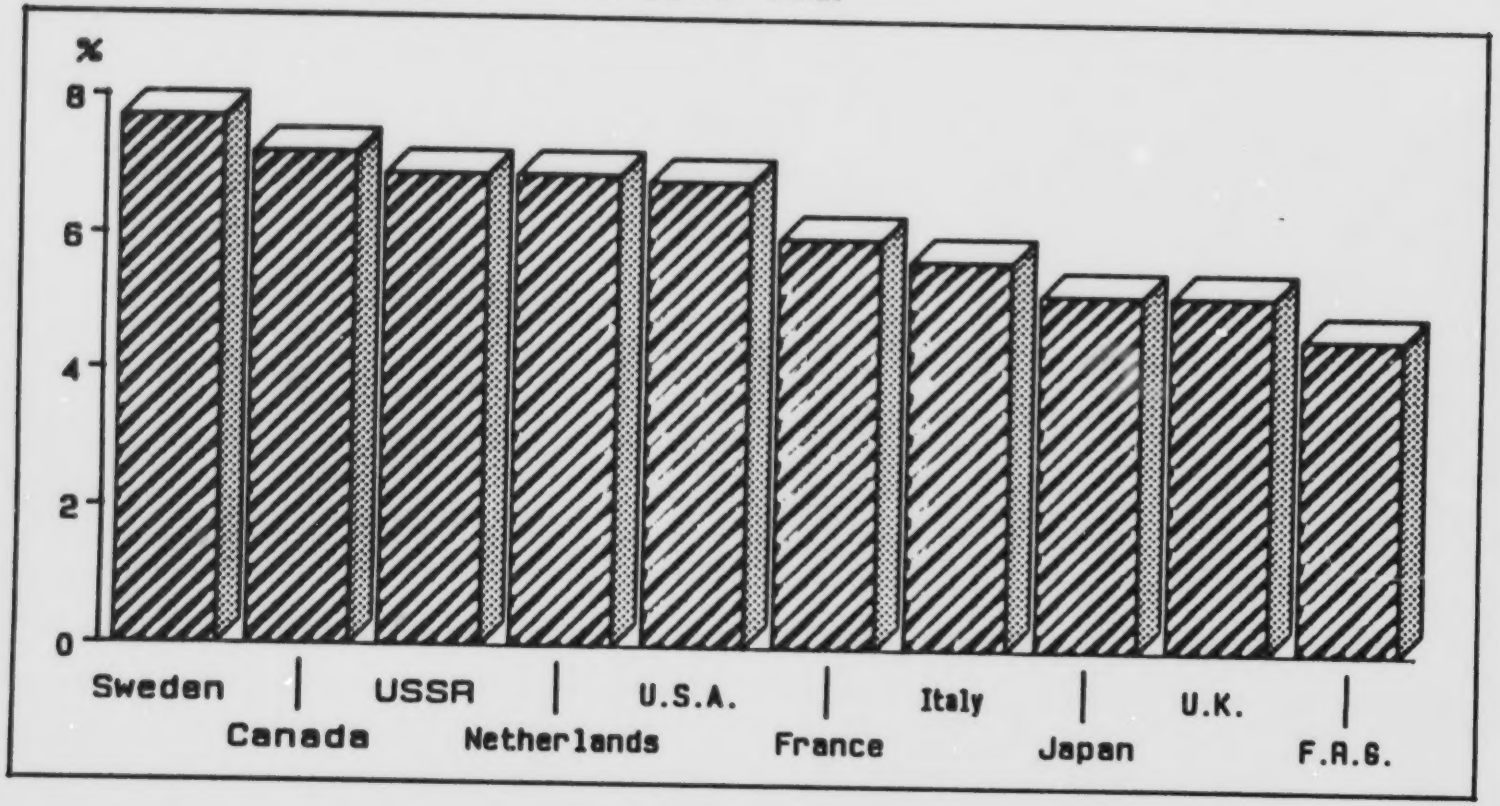


CHART 12

Postsecondary Enrollment as a Percentage of Population Ages 20-24, 1986 or Most Recent Available Year

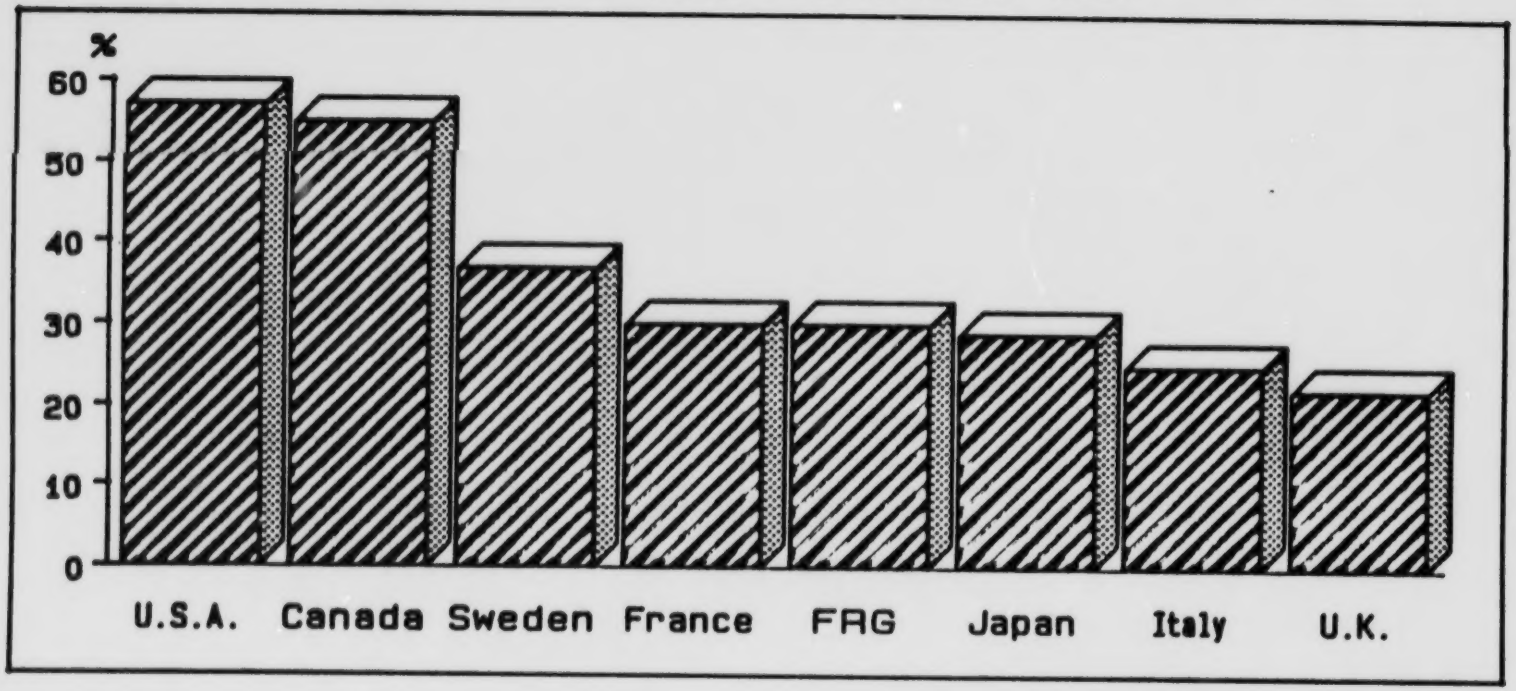


CHART 13

Results of International Mathematics Study for Students in Final Secondary Year, 1982

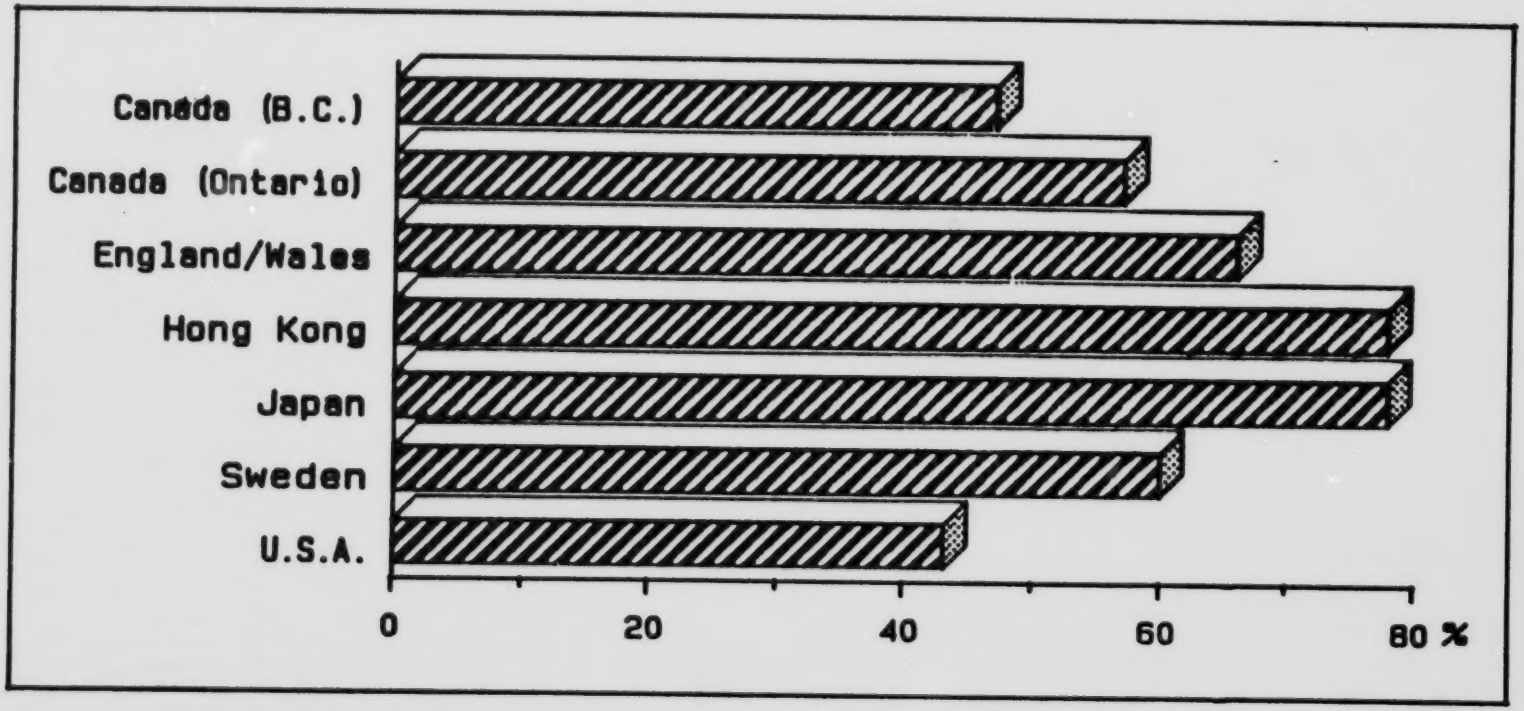
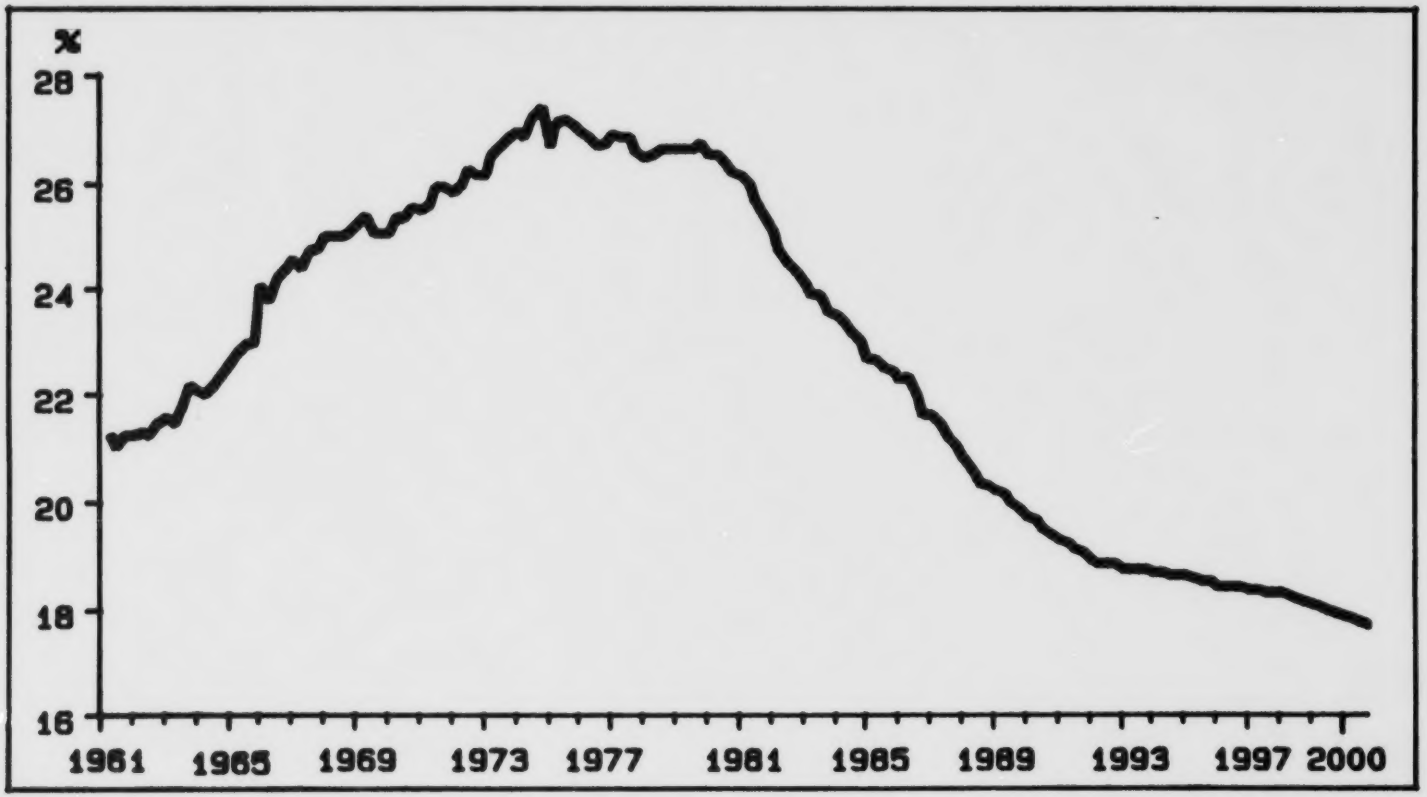


CHART 14

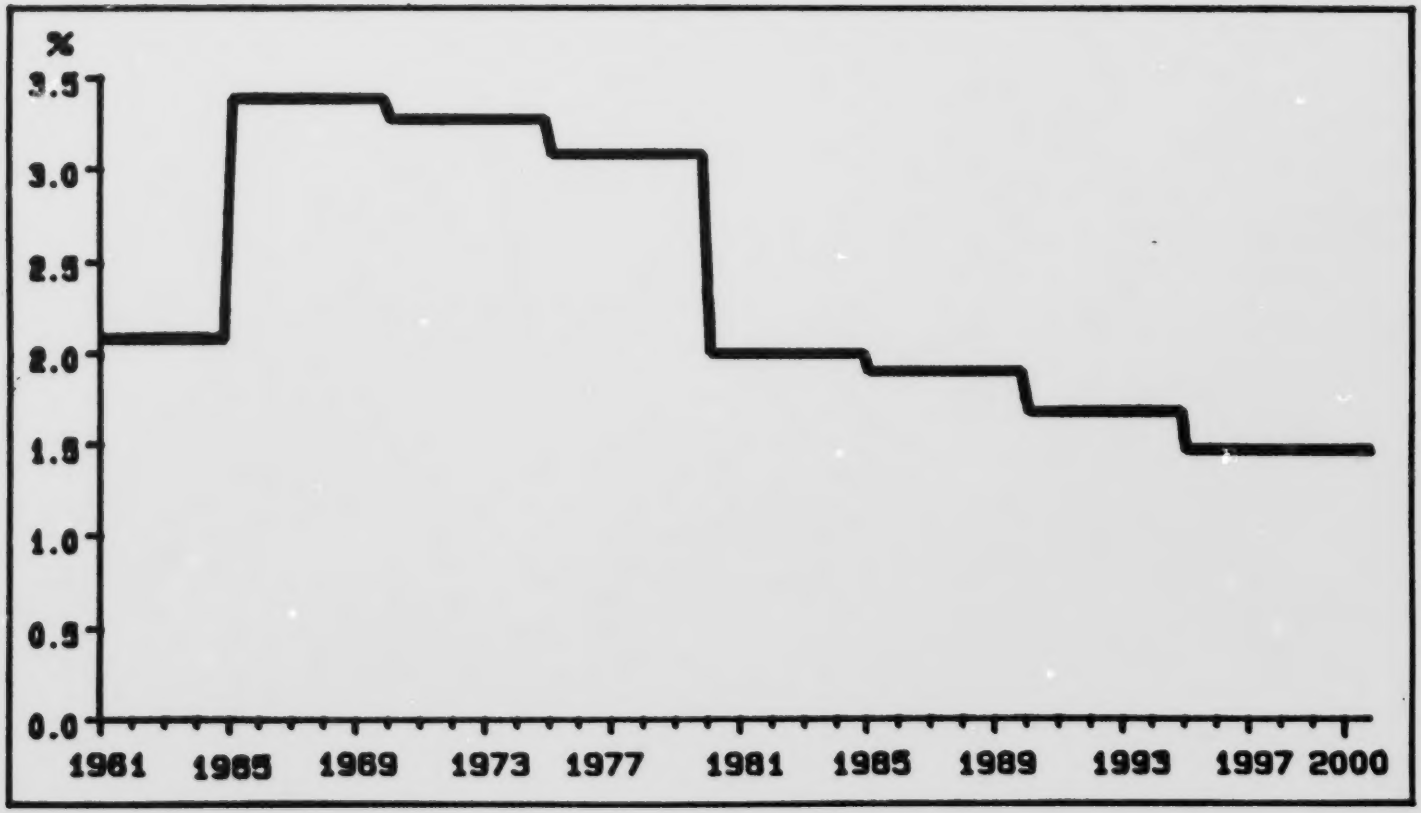
Demographic Constraints, 1961-2000
Youth (15-24 years) Share of Labour Force



Source: ECC.

CHART 15

Labour Force Growth Rate, 1961-2000
Five Year Averages



Source: ECC.

11/04/89

THE HUMAN RESOURCE BASE FOR SCIENTIFIC AND TECHNICAL ACTIVITY IN THE UNITED STATES

by

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Paper prepared for a meeting of the
Natural Sciences and Engineering Research Council of Canada
Ottawa, Ontario, Canada
May 3, 1989

The views expressed in this paper are solely those of the author. They should not be construed as those of the National Research Council.

INTRODUCTION

The importance of science and technology in fostering growth and well-being is generally unchallenged as a proposition. Equally unchallenged is the critical role played by the human resources devoted to this activity. Although equipment and facilities are important ingredients, working scientists and engineers, technicians and other support staff are its heart and soul.

Recent patterns of degree production and projected demographic and economic trends have given rise in many countries to concerns about whether the United States will be able to meet future needs for these critical, highly-skilled workers, particularly in academia. The purpose of this paper is to review briefly the major issues associated with this concern. These include:

the adequacy of the human resource base for meeting critical national needs as they are reflected in the demands of academia, industry and government for scientists and engineers;

the adequacy of mechanisms for altering the size and structure of this talent pool in response to shifts in national priorities; and

the adequacy of the resource base allocated to the production of the mathematics and science skills embodied in the entire population.

These issues are not easily assessed, particularly in the case of labor market balance and adjustment mechanisms used to achieve that balance. A major reason for this difficulty is that adequacy must be addressed in both quantitative and qualitative terms. The conventional measure of inadequacy (conventional, that is, to students of labor markets) is unfilled vacancies. These vacancies imply that employers are unable to attract a sufficient number of qualified applicants for their available science and engineering job openings at prevailing wages.

The absence of such vacancies do not necessarily mean that the supply of scientific and technical talent is adequate. When confronted with such vacancies employers may chose to lower their recruiting standards in order to fill their positions. In such circumstances a "qualitative" shortage could exist even though there were no unfilled job vacancies.

Similarly, the adequacy of the resource base devoted to the production of science and mathematics skills is difficult to determine since these skills are required for a range of activities that extends well beyond the needs for pursuing

scientific and technical careers. A widely-shared belief is that, as science and technology increasingly pervade our lives -- in the work place, at home, and in our communities -- a minimum amount of scientific and mathematical literacy will be required of everyone. A lively debate is now occurring over what that minimum should be and what it should consist of.

In the remainder of this paper, I will examine the current status of our knowledge base with respect to the human resource issues outlined above. I begin with an assessment of the current situation. I then turn to the future. First, I evaluate the issue of future adequacy; then I conclude with an examination of policies for coping with projected future inadequacies.

THE CURRENT SITUATION

At the current time, relatively few industrial employers report difficulties in meeting their staffing requirements for scientists and engineers, although spot shortages seem to exist in some fields of engineering (i.e. aeronautical, electrical, and electronics). In general, the reported recruiting difficulties center on experienced scientists and engineers. Recruiting new graduates does not appear to be as much of a problem. Conditions of shortage (i.e., an inability to find qualified applicants for job openings) were more widespread in the late 1970's and early 1980's. In the fall of 1986 about 28 percent of industrial employers responding to an NSF survey reported difficulties recruiting in at least one field of science or engineering, down from the more than one-half who reported such difficulties in the early 1980's. Similarly, the High Technology Recruiting Index -- a measure of the number of square inches of help wanted advertising appearing in technical and professional journals and magazines -- peaked in 1979 after experiencing dramatic growth in the 1970's and has not shown any further sustained growth since that time [Chart 1]. Thus, it appears that the current industrial labor market for scientists and engineers has moved closer to a situation of balance since the early 1980's. A major factor underlying this change was the deep recession experienced by the U.S. economy at that time.

Although the United States appears to be meeting its current quantitative needs for scientists and engineers, there is concern that it may be paying significant, but hidden, costs for achieving this goal in the form of a lower quality workforce of scientists and engineers. A recent study of engineering labor markets found, for example, that about one-half of the engineering job openings that were generated in the 1972-86 time period were filled from sources other than new engineering graduates. The major sources other than new degree recipients included degree recipients in closely-related fields and foreign-born engineers. [National Research Council, 1988b]. The potential costs of meeting industrial needs for scientific and engineering talent from these other sources of supply is that

they may provide workers who are either less productive than degreed engineers or they may be more costly because they require additional training to make them as effective as degreed engineers. [Fechter and Tuckman].

In academia, the problem appears to be centered in a small number of quantitative fields (engineering, physics, mathematics, computer sciences and economics). These fields are characterized by the high proportions of foreign students in their graduate programs and on their faculties. [Chart 2]. The origins of these recruiting problems seem to lie in the very lucrative industrial job opportunities open to American students who complete their bachelor's degrees in these fields (especially in engineering positions).

Although these foreign graduate students and faculty members make significant contributions to our academic research enterprise, their prominence evokes a number of concerns [National Research Council, 1988a; Finn, 1989] including:

(1) their teaching effectiveness (arising from possible language difficulties and/or cultural differences);

(2) constraints on their utilization in certain types of work (e.g., work requiring security clearances); and

(3) the effect of their presence in the scientific and engineering work force on market variables that would otherwise send signals of shortage to American students considering their career options.

In addition to the concern of the American policy community about the qualitative implications arising from the strong presence of foreign students and faculty members in our graduate schools interest has also centered on the failure of American students to pursue careers that require the doctorate and, among these students, the shrinking share that opt for academic careers. The number of American citizens and permanent residents who earned doctorates in natural sciences and engineering was 9,724 in 1987, roughly 3.3 percent of the doctorates with degrees in these fields that year.

This percentage has been trending downward steadily since 1973, when it was approximately 7.0 percent. [Chart 3] Assuming that losses due to deaths and retirements average around two percent per year, the current rate of degree production in these fields would not permit the doctorate work force to grow by much more than one percent per year, less than one-half the growth rate experienced by this workforce since 1973. [Finn, 1989] The earlier growth was supported increasingly by employment of new degree recipients who were foreign nationals on temporary visas. These foreign nationals accounted for roughly one-sixth of the estimated employment growth in 1973; they accounted for almost two-thirds of the estimated growth in 1987.

If these trends in degree production continue, future growth in doctorate employment in these fields will be slower and will be fueled almost entirely by foreign nationals on temporary visas. The consequences of these trends are already visible in engineering, where since 1981 more than one-half of the faculty below the age of 35 have been either foreign or naturalized Americans [Chart 4].

The data on science and engineering doctorates highlight another concern; that an increasing share of these new degree recipients are finding employment in nonacademic positions. [National Research Council, 1988c]. The major factor underlying this trend is the growing prominence of industry as an employer of doctorates [Chart 5]. It is not certain, however, whether this represents a fundamental and permanent change in the skill requirements of industry or a temporary shift in industrial demands arising from the recent dearth of employment opportunities for these doctorates in academia, their traditional primary employer. If it represents the former, then academia will be facing increased competition in recruiting these new doctorates in the future, when its demand is expected to increase dramatically.

THE FUTURE

As noted earlier, current patterns of degree production and expected demographic and economic patterns are giving rise to widespread concerns about the ability to supply the scientific and engineering talent that will be required to meet national needs as we enter the twenty-first century. The specific source of concern centers on current trends in degree production, which augur a future in which new degrees in science and engineering fields will not grow at the same that demand, in the form of job openings arising from employment growth and retirements, will be increasing dramatically.

Assessment of future degree production is difficult because this degree production reflects a complex process involving demographic factors and career choice behavior. Future bachelor's degree production depends on:

(1) the pool from which new degree recipients can be drawn; and

(2) the proportion of that pool who acquired degrees in these fields.

The latter proportion, in turn, reflects a number of behavioral variables:

(1) the fraction of that pool who completed high school;

(2) the proportion of these high school graduates who continued their schooling at the undergraduate level;

(3) the proportion of undergraduates who majored in science and engineering; and

(4) the proportion of science and engineering majors who completed training for bachelor's degrees in these fields.

Future doctorate degree production is also affected by:

(5) the fraction of bachelor's degree recipients in these fields who continued their training at the graduate level; and

(6) the fraction of these graduate students who completed the requirements for the doctorate degree in these fields.

Recent trends in these variables do not indicate strong future growth in degree production at either the bachelor's or the doctor's degree level. The pool from which these degree recipients can be drawn -- typically defined operationally as 22 year olds for the baccalaureate and 30 year olds for the doctorate -- has already been born. Thus projections of the size of this pool can be made with considerable certainty. These pools are expected to decline significantly over the next 5-10 years.

Evidence based on past relationships between the size of these pools and degree production suggest that this decline will be more of a potential constraint on growth for baccalaureates than it will for doctorates. [National Science Foundation, Division of Policy Research and Analysis, 1987; National Research Council, 1989]. The number of baccalaureates in natural sciences and engineering per one hundred 22 year olds has been relatively stable over a long period of time, hovering around 4.0 [Chart 6]. This suggests that the nondemographic variables affecting bachelors degree production have either been very flat or have had offsetting impacts. In recent years, however, the ratio of bachelor's degrees in these fields to the pool of 22 year olds has displayed a distinct upward trend, rising to 5.0. This upward trend has permitted the number of bachelors degrees in these fields to remain relatively stable despite the decline that has begun to occur in the 22 year old population. Given that this ratio is at an all-time high, it is not obvious that this trend can continue. If it does not, then bachelor's degree production in these fields can be expected to fall.

We are on less solid ground when it comes to forecasting values of the other, nondemographic variables. One indicator, however, the percent of undergraduate freshmen who plan to acquire degrees in these fields, does not provide much cause for optimism for the years beyond 1986. This percentage has been declining for natural science and engineering fields since 1982.

The relationship between the number of doctorates in natural science and engineering fields and the number of 30 year olds in the population is considerably looser [Chart 7]. For example, the number of doctorates awarded to American citizens and noncitizens who have permanent resident status has been falling since 1970; at the same time, the number of 25-34 year olds has been rising. [National Research Council, 1989].

A major factor underlying the declining trend in the number of doctorates produced over this period has been the decline in the rate of completion of the doctorate [Chart 8]. The number of doctorates produced annually in the natural sciences and engineering per 100 BS degrees produced seven years earlier declined by almost fifty percent between 1972 and 1979 and has been rising gradually since that time.

The loose link between Ph. D. production and the size of the pool from which Ph. D.'s are drawn and the substantial amount of variability in the Ph. D. completion rate suggests that future doctorate production in these fields may not be as inexorably linked to population trend as it appears to be for the bachelor's degrees. Part of the reason for this may be that doctorate production constitutes a substantially smaller share of the pool from which these degrees are typically drawn than is the case for bachelor's degree production. Thus, relatively small absolute changes in this ratio may offset the effects of the expected decline in the 30 year old population.

At the same time as the supply of new degree recipients is expected to grow more slowly (or to shrink), the demand, approximated by job openings, is expected to grow. In part, this growth will be fueled by increased replacement demand as larger numbers of the current scientific and engineering workforce approach retirement age. In engineering, for example, the death and retirement rate is expected to increase by one full percentage point. [National Research Council, 1988b]. In academia, the retirement rate is expected to increase by more than two percentage points. [Atkinson, 1989]. In part, this growth will occur as a result of projected new demand for these skills. Jobs for scientists and engineers are projected to increase by roughly 40 percent between 1986 and the year 2000. [U. S. Department of Labor, 1988].

COPING WITH THE FUTURE

Although it is not possible to generate forecasts of future supply/demand conditions with a tolerable degree of certainty, prudent policy would suggest preparing for a contingency in which demand growth will not be matched by comparable growth in new degree production. Under these circumstances, policy concerns center on measures to increase the pool from which new degree recipients can be drawn and/or to increase the share of this pool opting for degrees in science and engineering.

In attempting to increase the pool, policy makers have been devoting a considerable amount of attention to two areas: raising the yield from underrepresented groups -- women and members of non-Asian race/ethnic minority -- and increasing the mathematics and science content of precollege school curricula. The former area is particularly important because demographic projections indicate that in the future these underrepresented groups will constitute an increasing fraction of the pool. Thus the decline in degree production may exceed that which can be expected purely on the basis of the future size of the pool unless improvements can be made in the proportions of these groups who opt for, and successfully complete, degrees in science and engineering.

Accomplishment of this task will require policies that counselling and mentoring, and less social stereotyping of these groups in ways that discourage them from considering degrees in these fields.

Increasing the amount and quality of the mathematics and science coursework taken by students prior to their graduation from high school will clearly increase the pool of all students, regardless of whether they are members of underrepresented groups, with the requisite minimum training in these disciplines for the successful pursuit of degrees in these fields at the undergraduate level. Concern about the adequacy of math and science training at the precollege level goes beyond the perceived need to increase the pool from which new scientists and engineers can be drawn, however. There is widespread belief that these skills will become increasingly necessary to becoming a productive member of a more technologically oriented work force, regardless of whether one becomes a scientist or an engineer.

In attempting to increase the share of the pool that will opt for careers in science and engineering, policy makers have been concentrating on various mechanisms for providing financial support to students -- particularly at the graduate level -- in the form of fellowships. The cost of acquiring a doctorate in these fields (including the earnings foregone while in graduate school) is considered a significant barrier to the pursuit of this degree because of: (1) the substantial amount of time required to complete the degree (currently ranging from six to eight years in these fields); and (2) the lucrative earnings available to students who enter the work force with a bachelor's

degree in these fields (currently more than $30,000 per year in many engineering fields). [National Research Council, 1989; National Science Board, 1987].

Failure to achieve these goals will mean continued reliance on the other major sources of supply -- foreign students and Americans with degrees in closely related fields. For several reasons, this is not considered to be a desirable outcome. First, there is concern about the reliability of the foreign sources of supply, which could dwindle as a result of political instability or improved employment opportunities for scientists and engineers abroad. Second, as mentioned earlier, there are concerns about the qualitative implications of increased or continued reliance on these sources of supply. Given these concerns, one can expect to see continued strong emphasis placed on measures to increase the number of American students who opt for careers in science and engineering fields.

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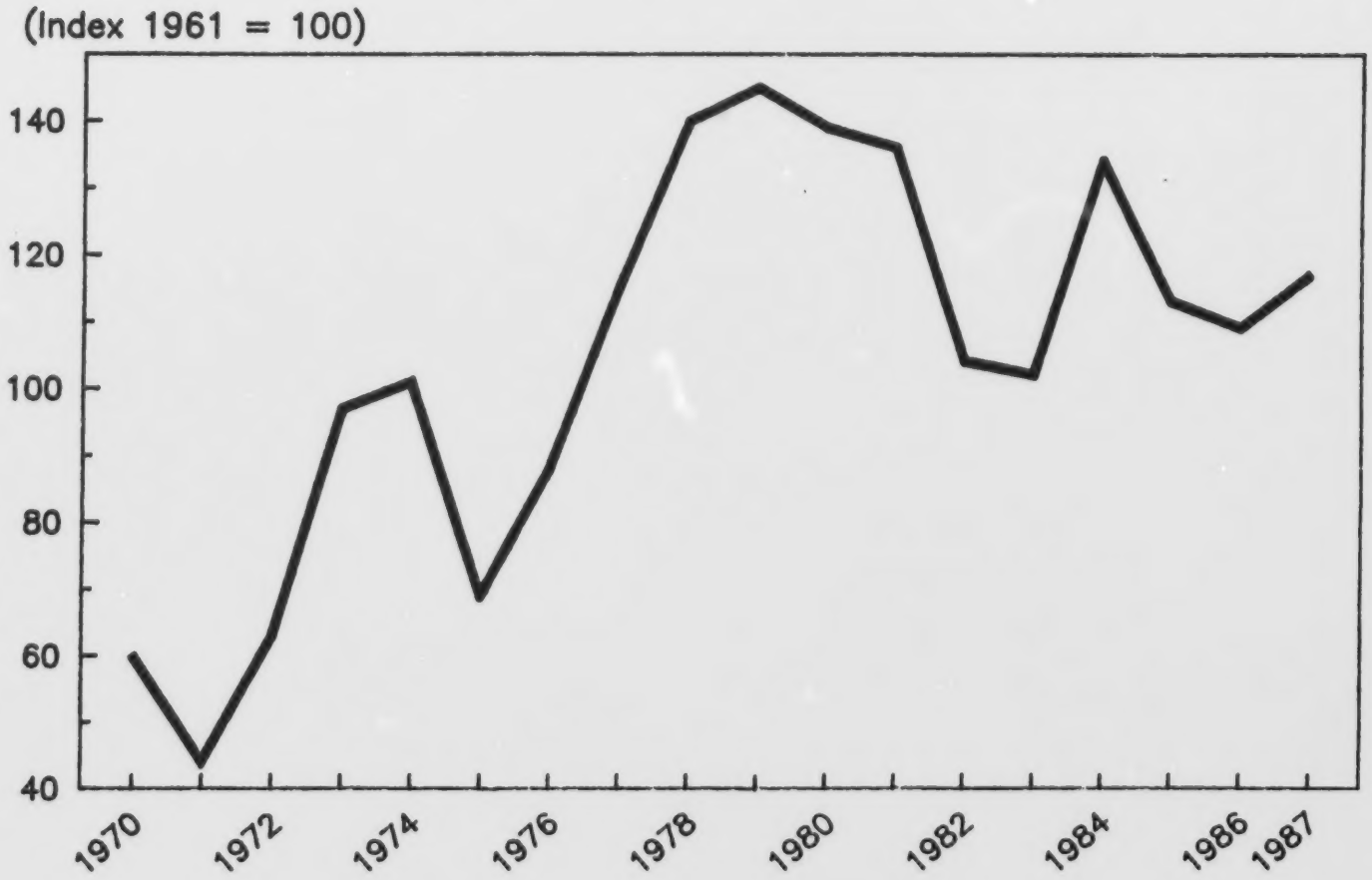
U.S. Department of Labor, Bureau of Labor Statistics, Projections, 2000, Bulletin 2302, Washington, D.C.: U.S. Government Printing Office, 1988

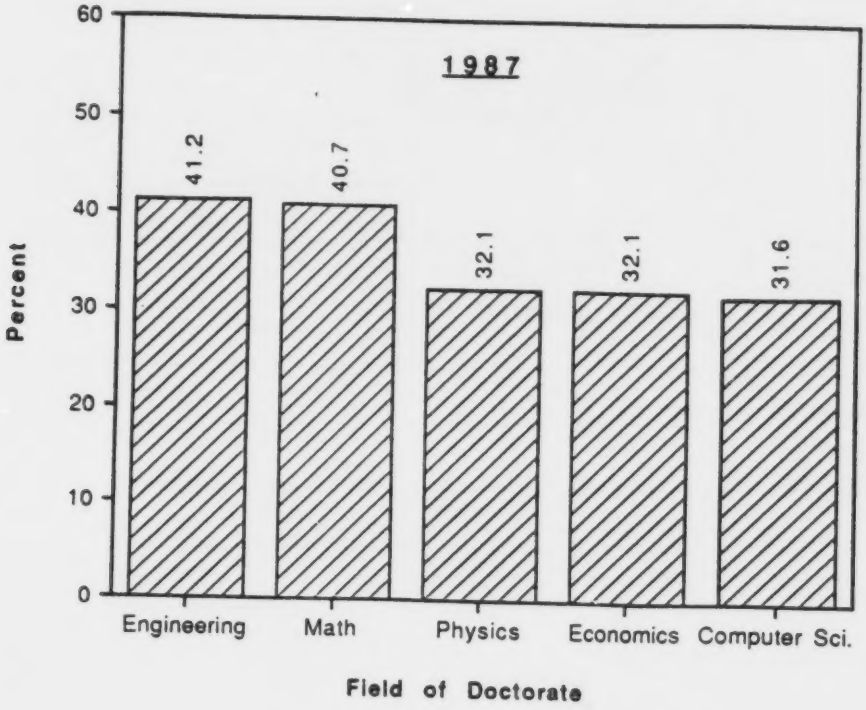
CHART 1

Deutsch, Shea, and Evans high technology recruitment index: 1970–87



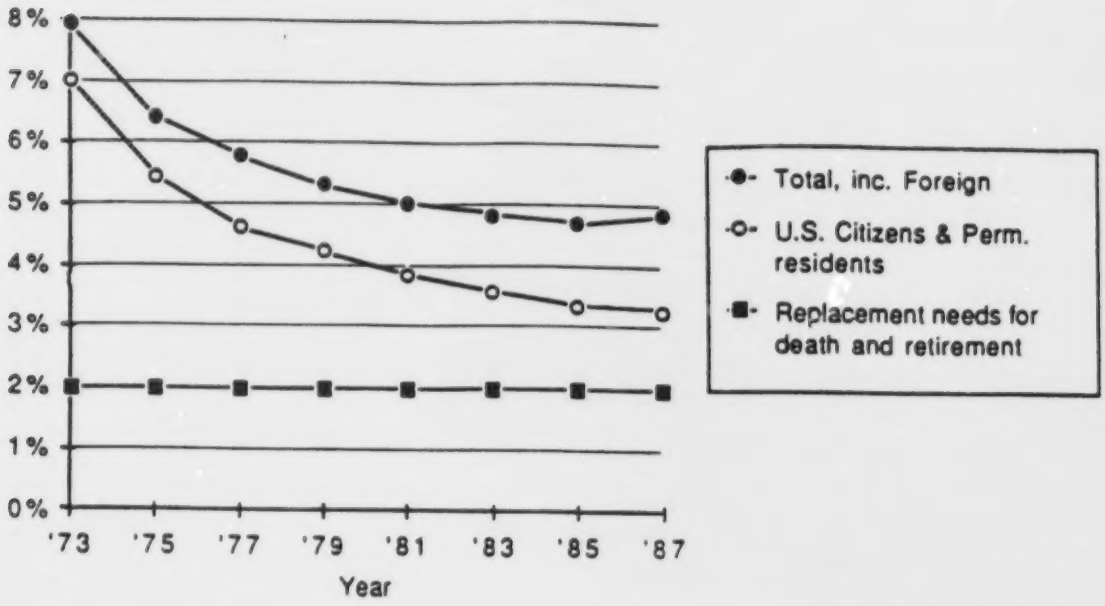
SOURCE: National Science Foundation, SRS; appendix table B–17

Chart 2. **Proportion of Doctorate Recipients Who Were Temporary Visa-holders**

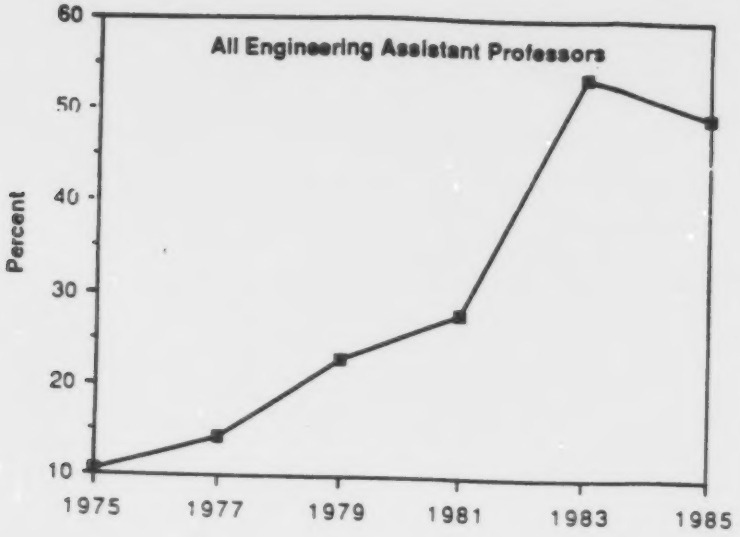


Source: National Research Council.

Chart 3. **New Doctorates as a Percentage of Total Employment of Doctoral Scientists and Engineers, 1973-1987**



Source: National Research Council, Survey of Doctorate Recipients and Survey of Earned Doctorates

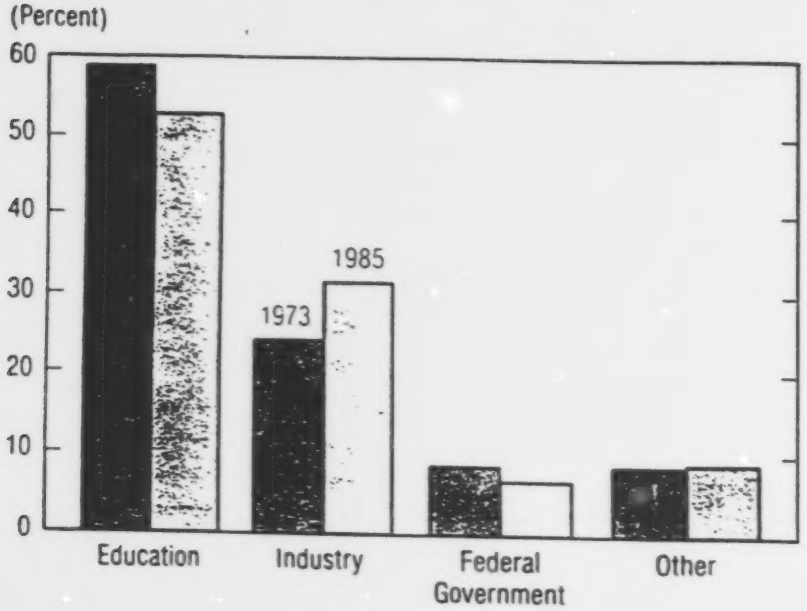


SOURCE: National Research Council's Survey of Doctorate Recipients.

Chart 4. Foreigners as a proportion of all engineering assistant professors, age 35 or less, 1975-1985.

Chart 5

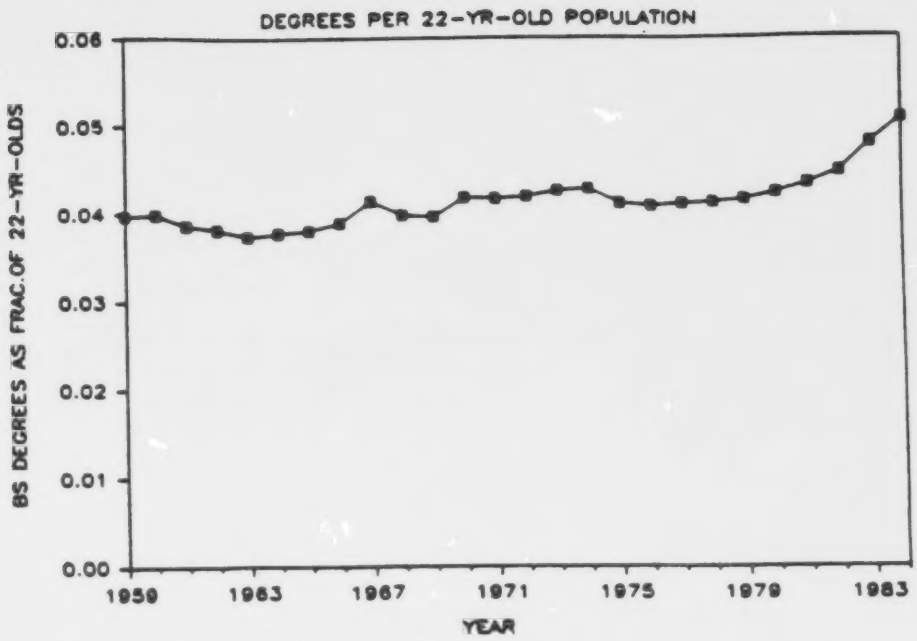
Distribution of employed doctoral scientists and engineers, by sector of employment: 1973, 1985



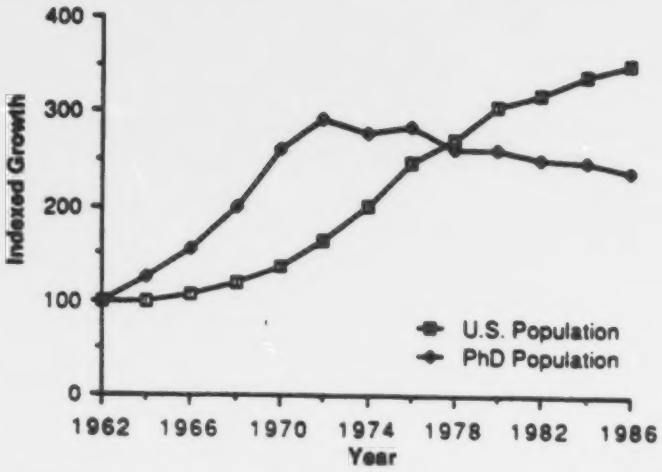
See appendix table 3-6.

Science & Engineering Indicators — 1987

Chart 6. **Bachelor's Degrees per 22-year-old Population**



Source: The Science and Engineering Pipeline
National Science Foundation, PRA Report 87-2,
April 1987.

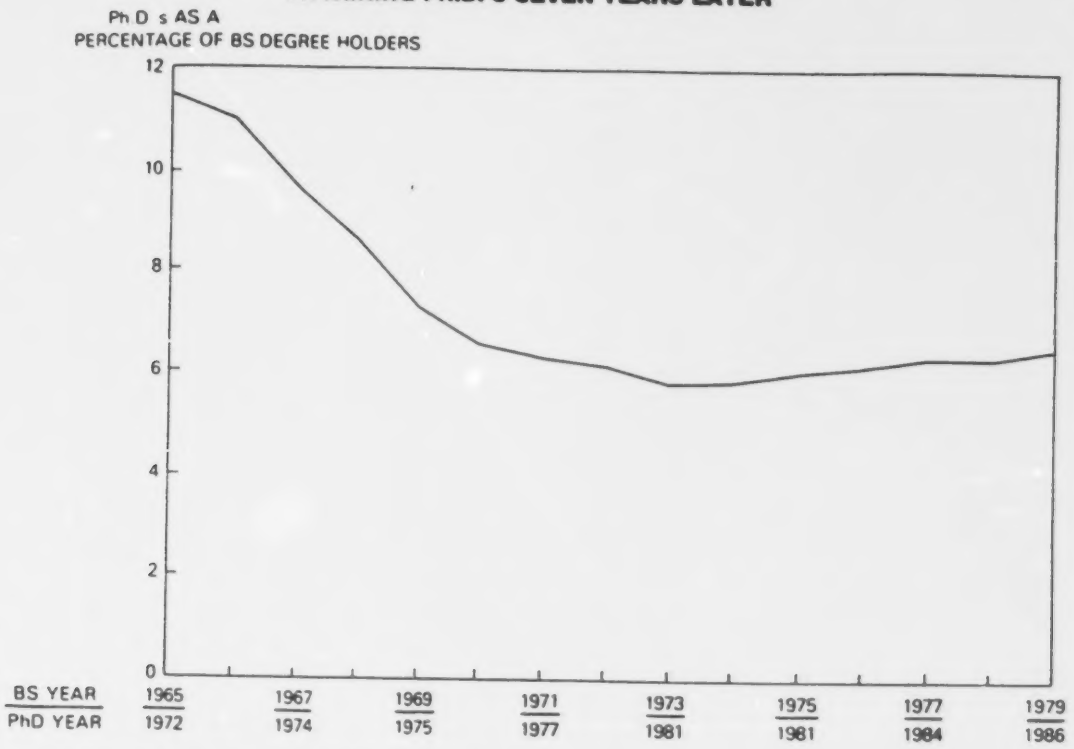


NOTES: Index year = 1962. Comparable U.S. population = 25- to 34-year-olds having 16 or more years of education.
SOURCES: National Research Council and U.S. Department of Commerce, Bureau of the Census.

Chart 7: Trends in the number of U.S. and permanent-resident Ph.D.s and in the comparable U.S. population, 1962-1986.

Chart 8

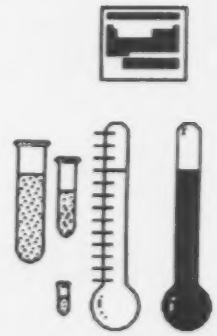
SCIENCE AND ENGINEERING BACCALAUREATES ATTAINING PH.D.'S SEVEN YEARS LATER



SOURCES: NATIONAL SCIENCE FOUNDATION, SRS AND CENTER FOR EDUCATION STATISTICS

SCIENTISTS AND ENGINEERS IN THE FEDERAL PUBLIC SERVICE /

SCIENTIFIQUES ET INGÉNIEURS DANS LA FONCTION PUBLIQUE FÉDÉRALE



Scientifiques et ingénieurs dans la fonction publique fédérale

Plan de la présentation

- Profil de la population
- Besoins futurs
- Disponibilité de la main-d'oeuvre
- Adaptation au nouvel environnement

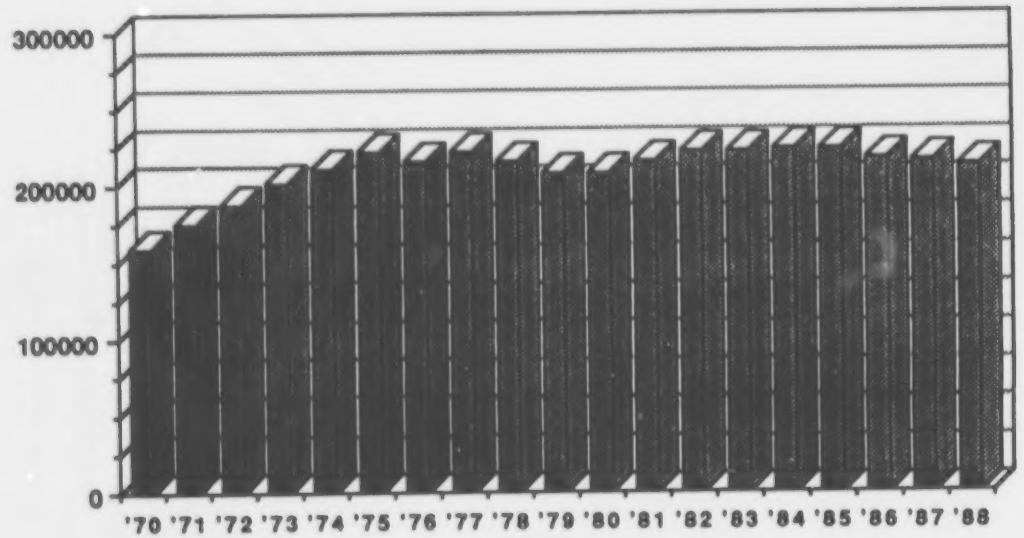
Population profile

- **Relevant Occupational Groups under the PSEA**

  - Agriculture (AG)
  - Biological Sciences (BI)
  - Chemistry (CH)
  - Defense Scientific Service (DS)
  - Engineering and Land Surveying (EN)
  - Forestry (FO)
  - Meteorology (MT)
  - Physical Sciences (PC)
  - Scientific Research (SE)

Profil de la population

- **Effectif (LEFP)**

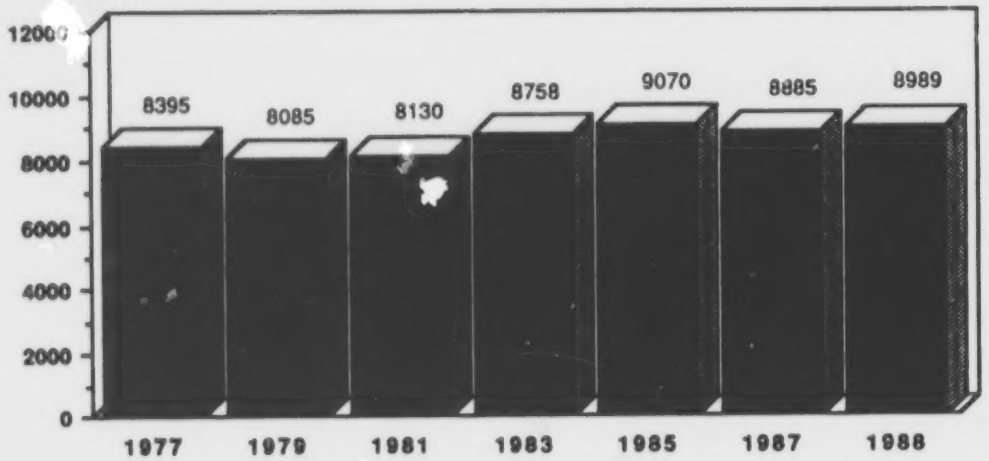


- De 1970 à 1975, une croissance constante a été enregistrée en ce qui concerne la population totale régie par la LEFP, l'effectif passant de 159 000 en 1970 à 222 000 en 1975. Depuis ce temps, cette tendance est demeurée relativement stable, en dépit des légères baisses enregistrées à la fin des années 70 et 80.

Année	Population régie par la LEFP
'70	158 948
'71	175 126
'72	187 201
'73	201 788
'74	211 165
'75	222 325
'76	216 103
'77	222 195
'78	216 136
'79	208 095
'80	208 299
'81	215 643
'82	222 582
'83	222 044
'84	224 026
'85	223 173
'86	217 223
'87	214 930
'88	211 993

Population profile

- **Population of Scientists and Engineers** (PSEA)



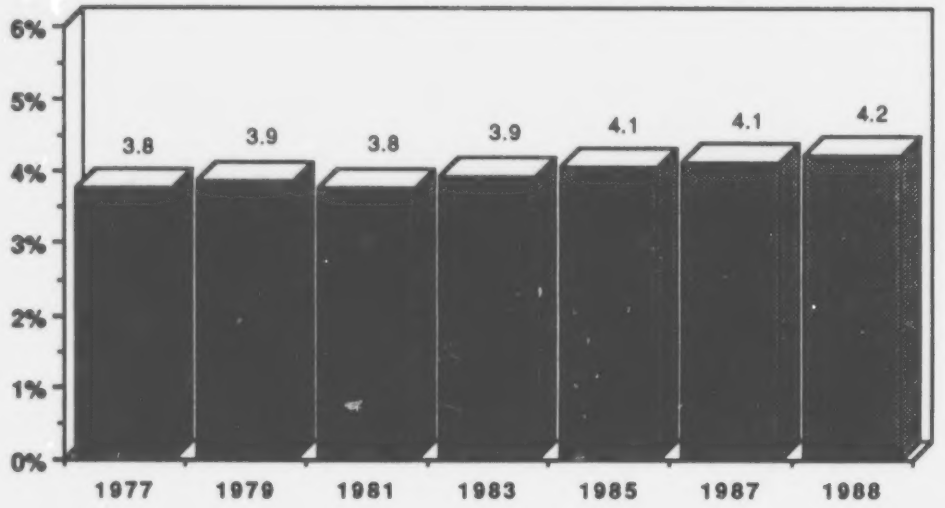
- *Between 1977 and 1988, the population of Scientists and Engineers in the PSEA population has fluctuated between 8 085 and 9 070*

- A trend similar to the one registered for the total population affected the population of scientists and engineers. A decline in population took place at the end of the seventies and at the end of the eighties with a small increase between these two periods.

- *Over the last five years, the size of the population has remained relatively stable.*

Profil de la population

- **Pourcentage des scientifiques et ingénieurs (LEFP)**



- Le pourcentage des scientifiques et ingénieurs a été relativement stable pendant la période 1977-1988.

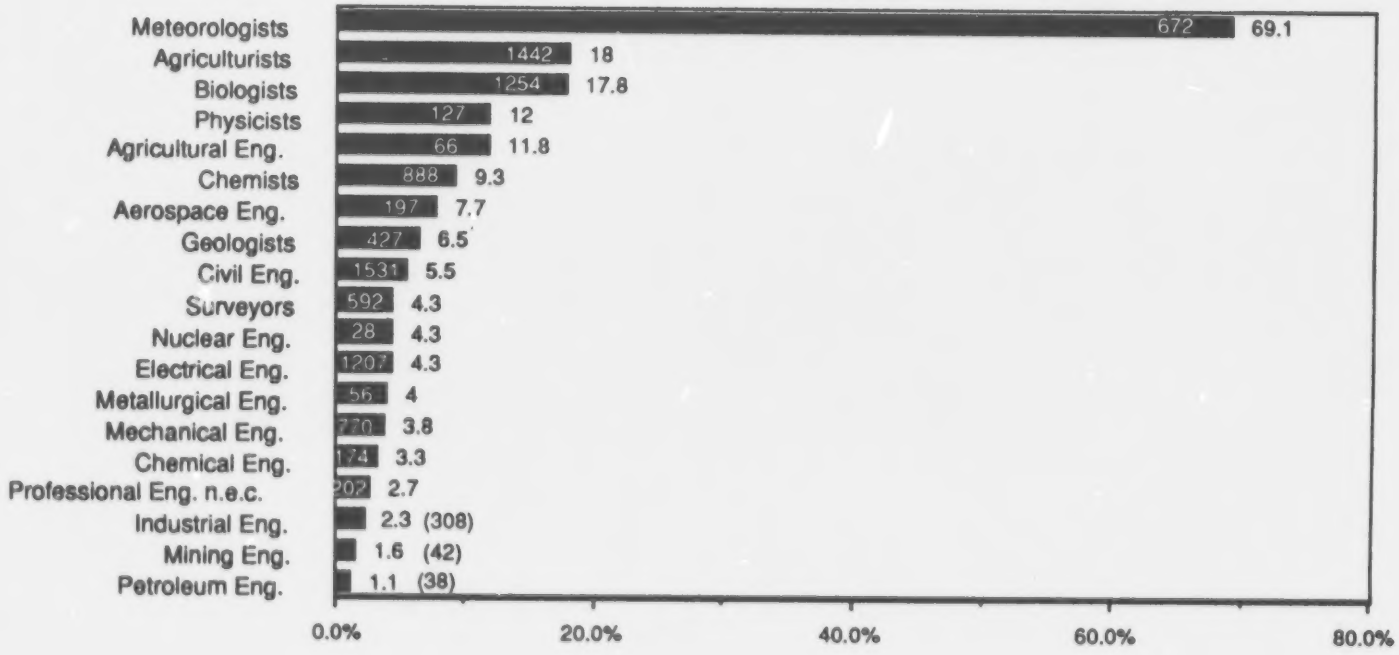
- Avec une population variant entre 8 000 et 9 000 fonctionnaires, les scientifiques et ingénieurs représentaient environ 4% de l'ensemble de la population régie par la LEFP.

Année	% de la population
1977	3,8%
1979	3,9%
1981	3,8%
1983	3,9%
1985	4,1%
1987	4,1%
1988	4,2%

- La légère augmentation enregistrée au cours des dernières années pourrait bien être liée à l'accroissement du caractère professionnel de la fonction publique ainsi qu'à une moins grave répercussion des programmes de réduction des effectifs sur la population des scientifiques et ingénieurs.

Population profile

- **Scientific and Engineering Labour Force working in the Federal Administration Industry** (1986 Census)



- The above figures are based on the 1986 Census of Canada and cover the total "Federal Administration Industry" (excluding Armed Forces);

- The "Federal Administration Industry " definition is based on Statistics Canada's Standard Industrial Classification. Therefore, crown corporations such as Air Canada, CN, and Canada Post are not included. However, it includes all separate employers such as Parliament, Federal Courts, etc.

- For some occupations, it shows that the federal government is a major employer and in competition with the other industrial sectors on the labour market;

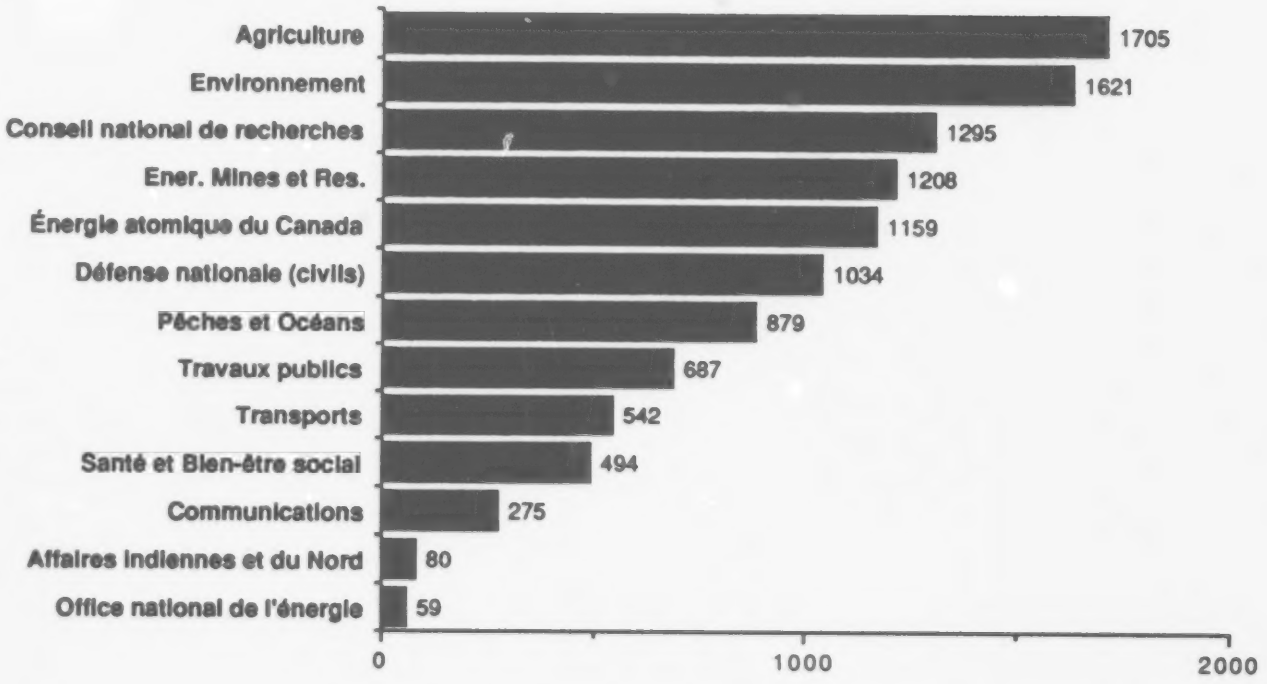
- It is interesting to note that the federal public service employed approximately 70% of all meteorologists in Canada;

- Approximately 1 out of every 5 biologists and agriculturalists in Canada works for the federal government;

- In the federal Public Service (PSEA), the engineers (EN) and research scientists (SE-RES) account for about 56 percent of the total number of scientists and engineers.

Profil de la population

- **Scientifiques et ingénieurs par ministère**



- **Agriculture**: la plupart des scientifiques y sont des chercheurs scientifiques (SE-RES), des agronomes (AG) et des biologistes (BI);

- **Environnement**: Météorologues (MT), ingénieurs (EN), spécialistes des sciences physiques (PC), biologistes (BI) et chercheurs scientifiques (SE-RES);

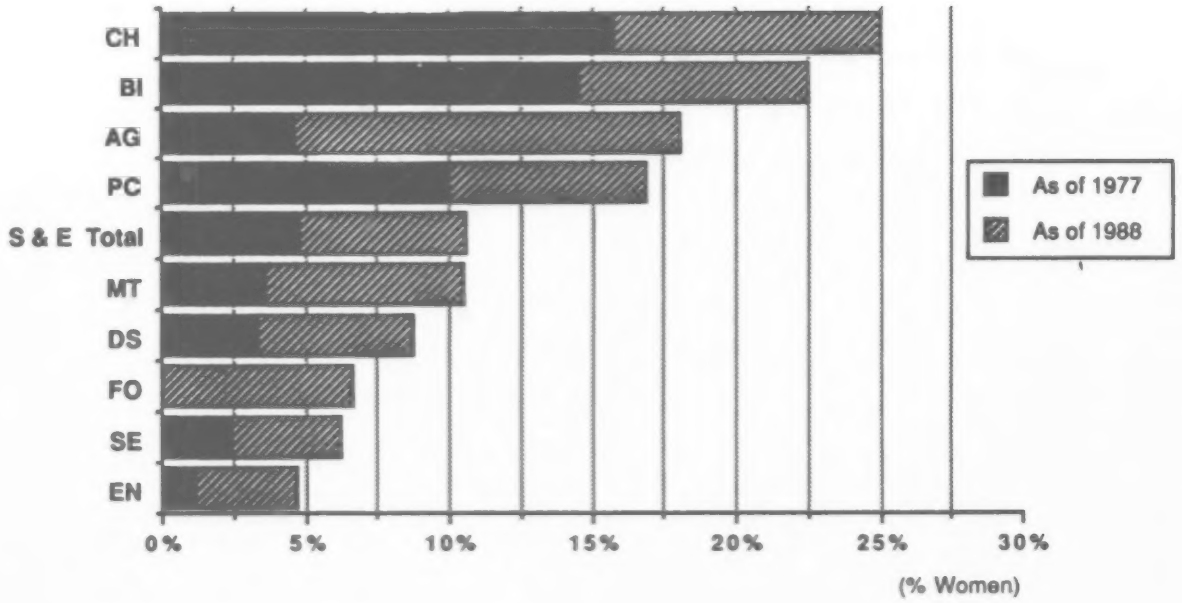
- **EMR**: la plupart des scientifiques y sont des chercheurs scientifiques (SE-RES), des spécialistes de sciences physiques (PC), ingénieurs et arpenteurs (EN);

- Le graphique indique clairement qu'un nombre considérable de scientifiques et d'ingénieurs (au CNRC et à Energie atomique du Canada) ne sont pas nommés aux termes de la LEFP et ne sont pas comptés dans les chiffres présentés dans la plupart des autres tableaux.

**Les données concernant les ministères régis par la LEFP et le CNRC correspondent à l'année 1987, celles pour Energie atomique du Canada sont en date de février 1989.

Population profile

- **Representation of Women** (PSEA pop.)



- The representation of women among scientists and engineers has improved in all occupational groups;
- Overall, the representation of women went from 4.8% to 10.6% during that period

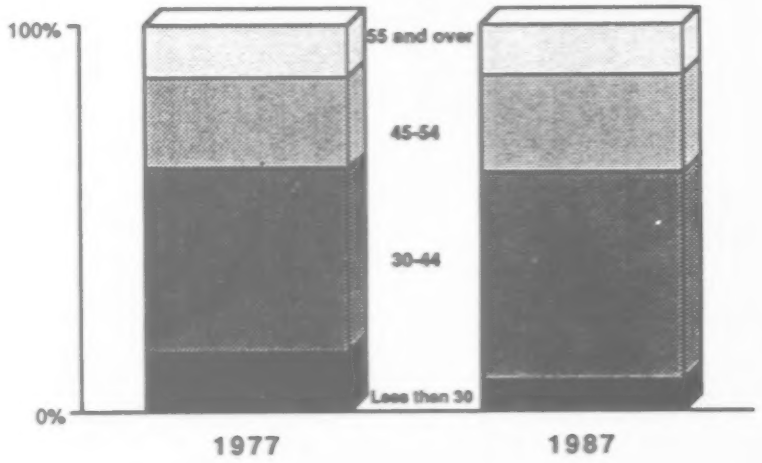
Occ. Group	1977	1988	Change '88-77 (points)
CH	15.8%	25.0%	9.2
BI	14.5%	22.5%	8.0
AG	4.6%	18.1%	13.5
PC	10.0%	16.9%	6.9
MT	3.6%	10.5%	6.9
S & E Total	4.8%	10.6%	5.8
DS	3.4%	8.7%	5.3
FO	0.0%	6.6%	6.6
SE	2.4%	6.2%	3.8
EN	1.2%	4.7%	3.5

- The Agriculture Group showed the greatest improvement in percentage points (13.5)

Population profile

- **Age structure**

Scientists and Engineers Age groups



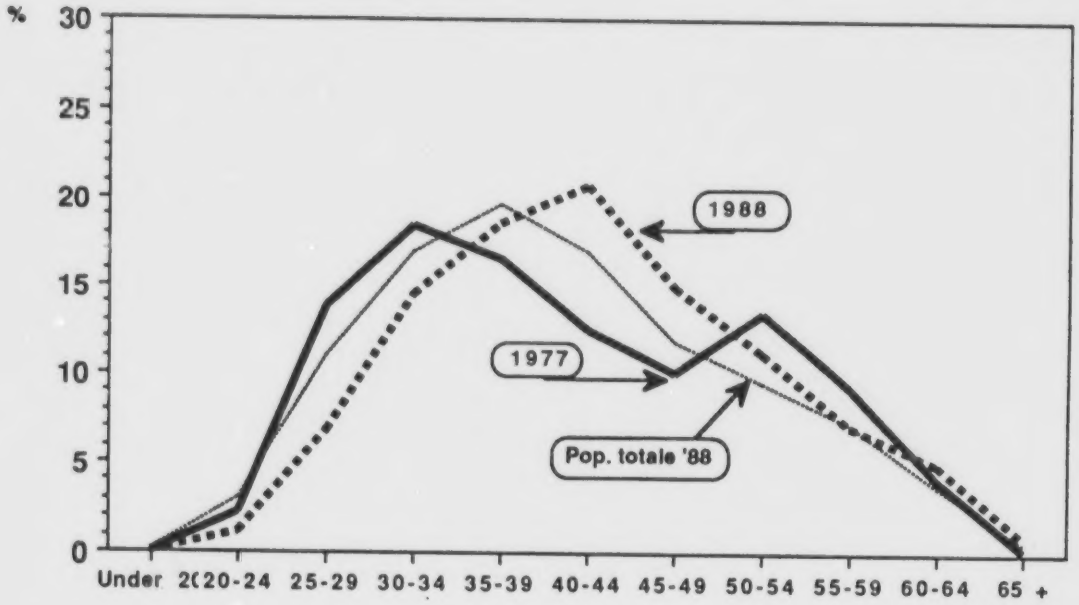
- Like the rest of the Public Service, scientists and engineers are aging as this graph indicates;
- Between 1977 and 1987, the number of those aged less than 30 decreased by 42 % . In 1987, only 9% of the scientists and engineers were less than 30 years old;
- At the other end, the number of persons aged 55 and over grew by 4 % while the 30-44 cohort increased in strength by 21 %;
- When a population is not growing in number and that the inflow of new employees in the younger age groups is limited, the aging process changes the relative importance of the various cohorts seen in this graph;

Age Groups	1977	1987	% Change
Less than 30	1,324	770	- 42
30-44	3,919	4,737	21
45-54	1,945	2,227	14
55 and over	1,112	1,151	4

Profil de la population

- **Composition selon l'âge**

Répartition d'âge des scientifiques et ingénieurs comparée au total de la population régie par la LEFP



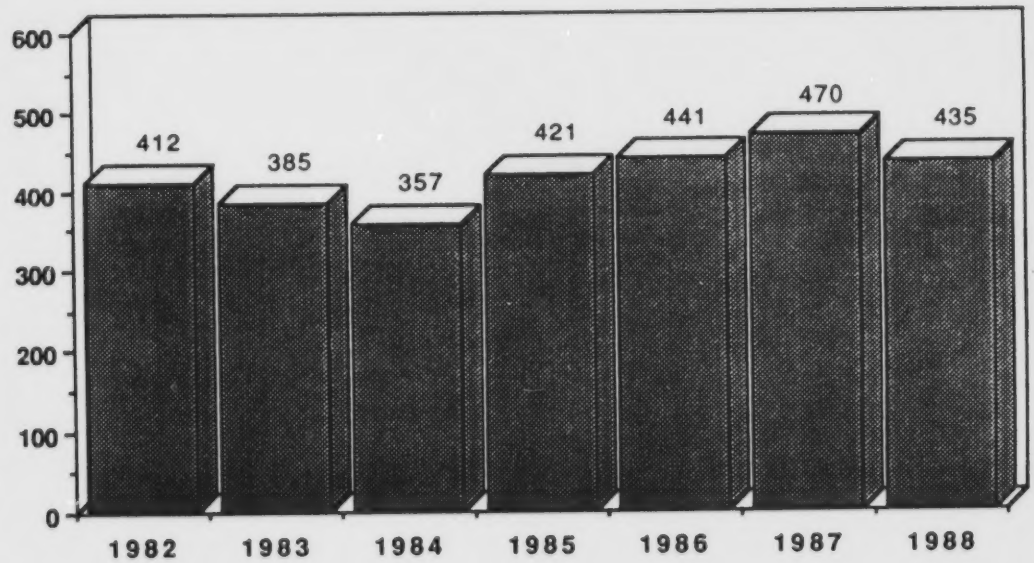
Ce graphique, illustre d'une autre façon les variations dans la répartition des scientifiques et ingénieurs en fonction de l'âge. Deux constatations en ressortent:

a) Les fonctionnaires recrutés dans les années '70 étaient alors dans la trentaine et sont maintenant dans la quarantaine avancée. Si la situation se maintient, il est à prévoir que le sommet de la courbe se déplacera au groupe d'âge 50 à 54 ans. Une telle situation donnerait lieu à d'importants problèmes de ressourcement car les membres de ce groupe commencent alors à prendre leur retraite.

b) La répartition des scientifiques et ingénieurs par groupes d'âge tend plus vers la droite que la courbe moyenne pour l'ensemble de la fonction publique. Cela indique que les problèmes causés par le vieillissement des effectifs de la fonction publique risquent d'être encore plus graves dans le domaine de la recherche scientifique. Dans un domaine où les changements sont rapides et continuels, il est fortement souhaitable de maintenir un apport constant de nouveaux chercheurs afin d'aider l'organisation à se maintenir à la fine pointe du progrès. Ce n'est cependant pas ce qui s'est produit dans les ministères fédéraux au cours des dernières années ainsi que l'illustrent les tableaux suivants.

Besoins futurs

- **Départs des scientifiques et ingénieurs** (LEFP)

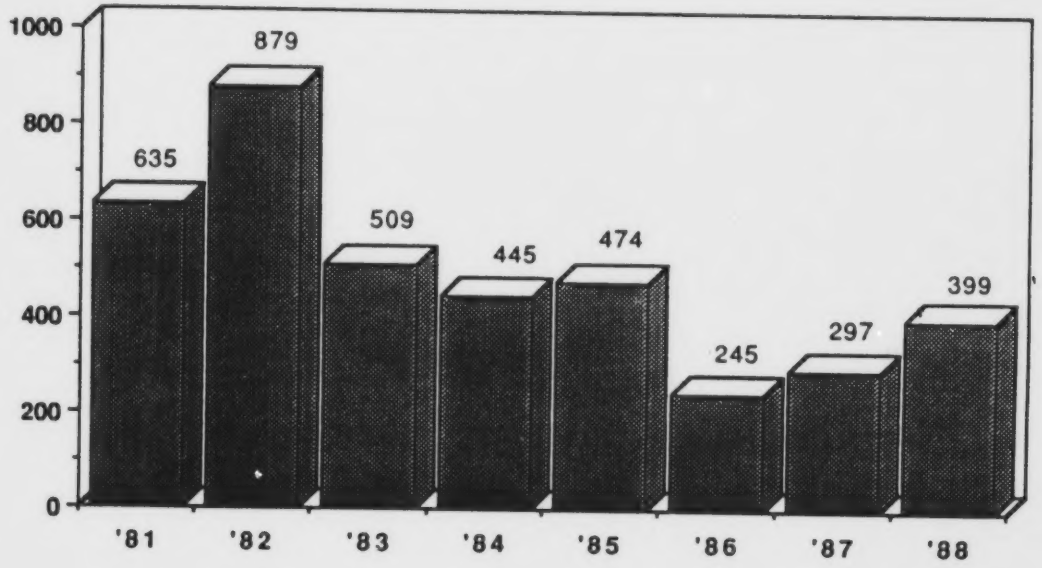


- Au cours des sept dernières années, 417 scientifiques et ingénieurs en moyenne ont quitté la fonction publique chaque année; depuis 1984, cette tendance s'est encore accentuée;

- Le taux des départs pour cette population de scientifiques et d'ingénieurs en 1988 est inférieur à la moyenne. Les taux des départs pour les scientifiques et ingénieurs ont varié entre 4 et 5% au cours des dix dernières années, par comparaison à 8 et 10% pour l'ensemble des effectifs régis par la LEFP.

Future Requirements

- **Recruitment levels of Scientists and Engineers** (PSEA)



- Following the service-wide trend, the recruitment of scientists and engineers show a general downward trend. In 1986 and 1987, less than 400 were recruited. Between 1981 and 1988, an average of 485 recruits were hired;

- Departments with delegated external recruitment authority for scientific groups were contacted to get their perceptions of the current and future requirements. The following commentaries were obtained:

  - **restraint** has affected recruitment activities over the last few years;
  - in some fields such as research science, departments see the need to **rejuvenate** the group and increase recruitment;
  - it is sometimes difficult to find applicants with the specialties required;
  - managers often rely on their colleagues or university contacts to identify suitable candidates;
  - departments are also interested in increasing the representation of employment equity group members in the scientific field;
  - at the moment, there does not appear to be any problem either existing or foreseen in recruiting **agricultural officers** or **chemists**;
  - at times, it is difficult to find **biologists** in some specialties;
  - it would appear quite definite that the recruitment of **engineers** should be augmented in order to satisfy the needs of a number of departments;
  - sometimes, there is **difficulty in attracting** engineers to work for the Public Service.

Disponibilité de la main-d'oeuvre

- Tendances démographiques
- Diplômés universitaires

- Même si aucun risque sérieux de pénuries éventuelles de ressources n'est à craindre à court terme, il faut cependant tenir compte des autres facteurs qui peuvent aussi avoir des répercussions à moyen terme;

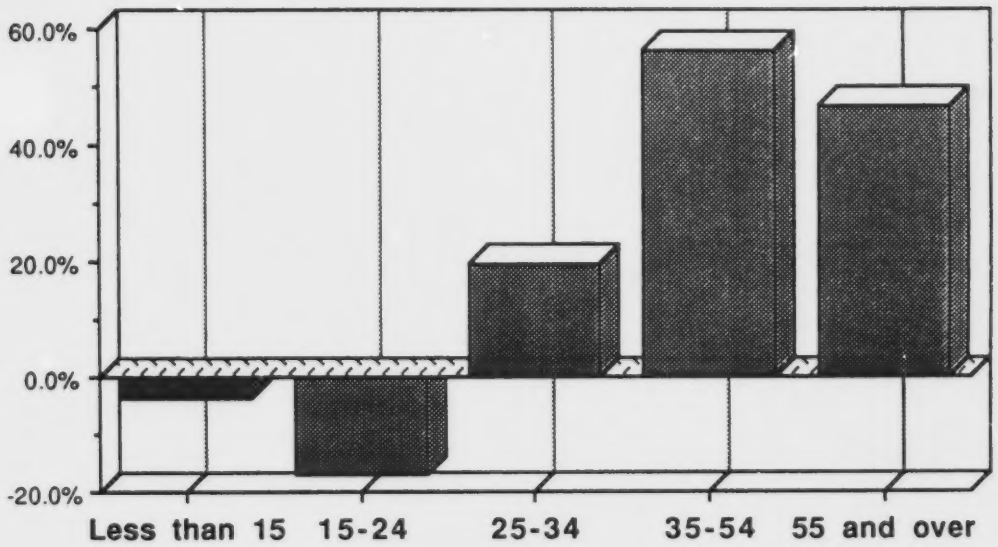
- L'un des plus importants facteurs concerne les changements démographiques qui détermineront la disponibilité de la main-d'oeuvre au cours de la prochaine décennie;

- Il faudra aussi tenir compte de l'arrivée des nouveaux diplômés qui constitueront les futurs effectifs de scientifiques et d'ingénieurs.

Labour Supply Considerations

- Demographic trends

Percentage change in the Canadian population 1977 to 1995

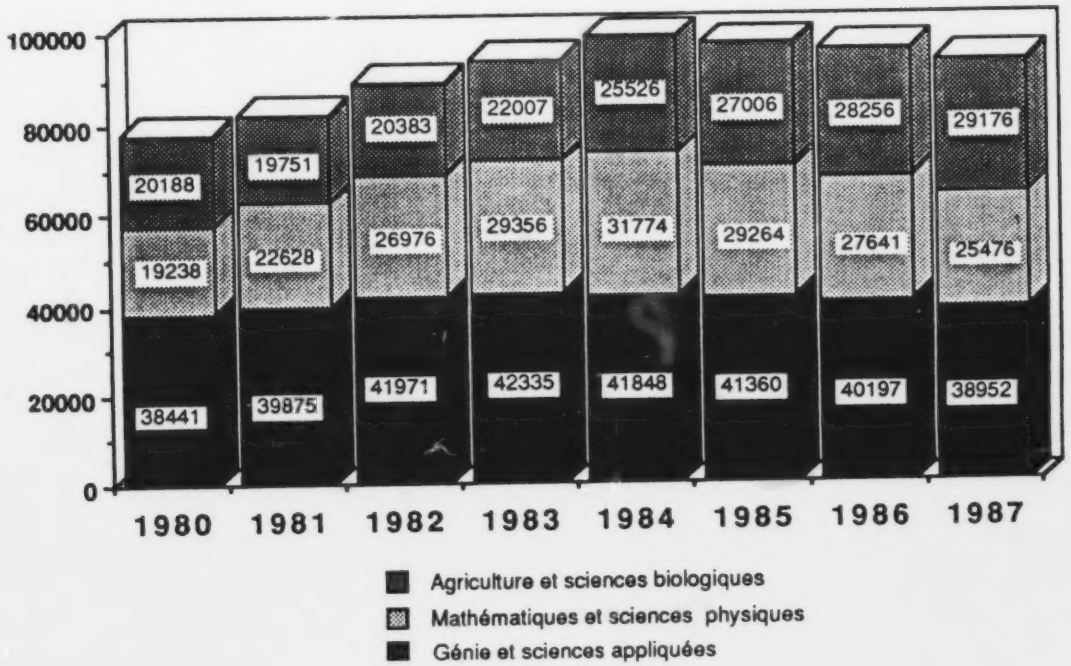


- The Canadian population will experience some major shifts in the relative importance of some of its cohorts;
- Of special interest is the diminishing size of the cohort of those aged less than 25, our future recruits. Just between 1977 and 1995, this age group will have undergone a significant reduction of 17.2% in its size;
- Therefore, one of the major sources of new labour supply is declining ;
- At the other end of the scale , the mature age groups benefit from important increases;
- The implications may be very important, specially if the increase in economic activity is greater than expected; competition between employers will become fierce and shortages in specific fields more and more acute;
- New strategies will need to be developed to attract and keep employees (a subject that is discussed later in this presentation)

Age group	% Change
Less than 15	-3.9%
15-24	-17.2%
25-34	19.6%
35-54	56.1%
55 and over	46.6%
Total	19.3%

Disponibilité de la main - d'oeuvre

- **Inscriptions dans des programmes universitaires de premier cycle en sciences**



Scientifiques et ingénieurs dans la fonction publique fédérale

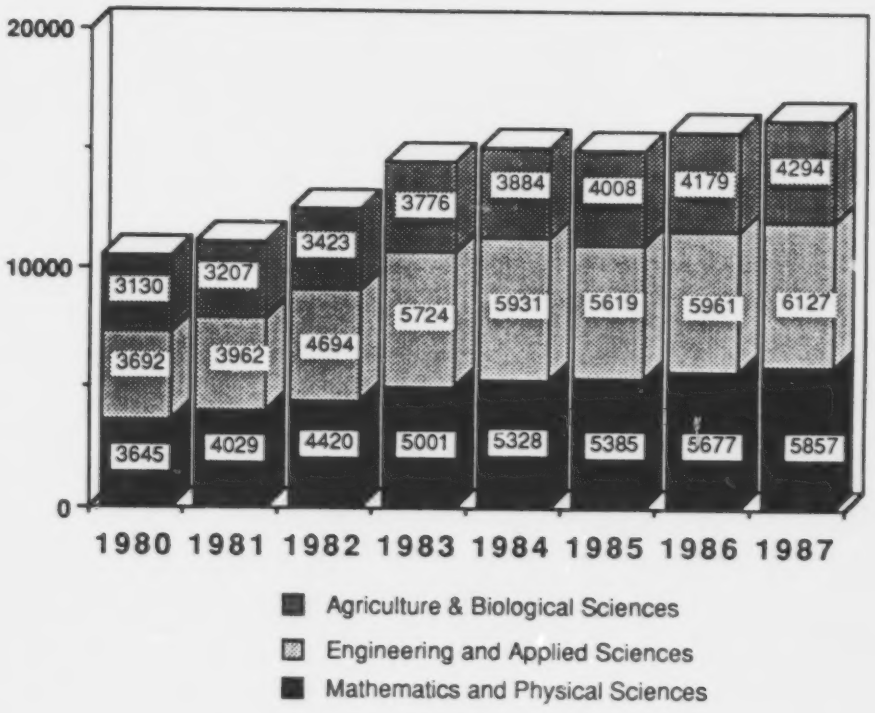
- Le nombre total d'étudiants inscrits (temps plein et temps partiel) aux programmes de sciences naturelles et de génie, au cours de la présente décennie, a atteint son plus haut niveau en 1984 lorsque les universités ont admis près de 100 000 candidats (99 148 pour donner le chiffre exact);

- Depuis cette date (1984) et très probablement en raison de la baisse enregistrée dans la population des jeunes, le total des inscriptions dans les programmes en question a diminué de plus de 5% en trois ans (93 604 admissions en 1987);

- Il faudra ainsi tenir compte du fait que depuis 1984, l'importance des programmes scientifiques ait varié d'une discipline à l'autre. Alors que pour les programmes d'agriculture et de biologie, le nombre d'étudiants a augmenté de 16%, les programmes de génie et de sciences mathématiques et physiques ont enregistré une baisse de 7% et 20% respectivement au total des admissions.

Labour Supply Considerations

- **University Enrollments in Scientific Fields of Study : Graduate Level**



- Undergraduate studies and Graduate studies are link in time since everybody as to complete the first level in order to access to the second level. That may explain in part the reason why the decline observed at the undergraduate level is still not apparent at the Graduate level. It is probably in the years to come that it will impact.

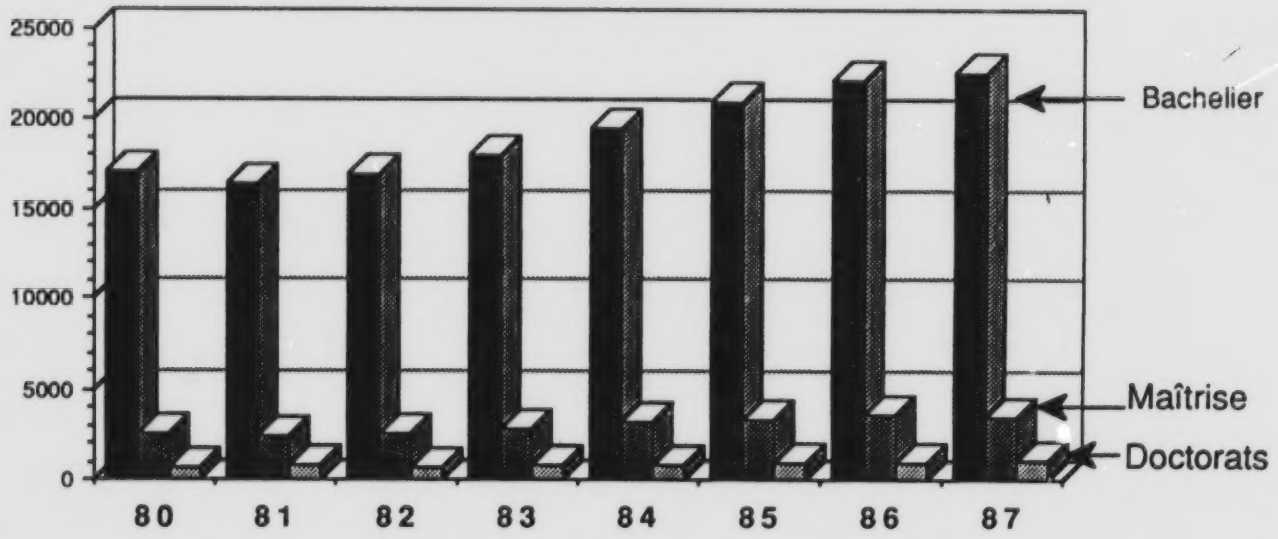
- Between 1980 and 1987, total enrollments in these three scientific fields increased overall by 56% . Engineering , Mathematics and Physics saw their enrollments grow by more than 60% as opposed to only 37% in Agricultural and Biological Sciences.

- In summary, the continuing and growing influx of students entering these fields during the eighties has alleviated the labour shortages that some were anticipating at the start of this decade. However, the more recent trends show that this situation will not prevail for a very long period during the nineties. The source of new talent will soon start to diminish.

Disponibilité de la main - d'oeuvre

- **Diplômés**

Diplômés spécialisés en sciences naturelles et en génie



Scientifiques et ingénieurs dans la fonction publique fédérale

- Quand on considère le nombre de diplômés spécialisés en génie et en sciences naturelles, on se rend compte que le total des bacheliers a presque plafonné au cours des trois dernières années;

- Le nombre de diplômés du deuxième cycle (maîtrise) a diminué entre 1986 et 1987, alors qu'en troisième cycle (doctorat), on a plutôt enregistré une hausse depuis 1984;

- Dans ces conditions, il ne faudra pas s'attendre, dans un proche avenir,à une augmentation soudaine du nombre de scientifiques hautement qualifés disponibles;

- Un nombre relativement constant, si ce n'est décroissant, de diplômés fera son entrée sur un marché du travail où une demande accrue pour ces spécialistes se manifestera.

DIPLOMES SPECIALISES EN SCIENCES NATURELLES ET EN GENIE, de 1980 à 1987

Année	Baccalauréat	Maîtrise	Doctorat
80	17074	2493	735
81	16427	2343	776
82	17007	2590	722
83	18096	2742	807
84	19516	3186	798
85	20985	3342	910
86	22171	3669	987
87	22574	3505	1119

Coping with the new environment

- **Recruitment and Referral Study**
- **Other initiatives**

- One of the objectives of the Commission is to ensure a highly competent Public Service;

- Realizing that the next decade will be a challenging one for employers who want to attract the best and the brightest, the Commission undertook some major initiatives to cope with this future environment;

- An in-depth review on Recruitment and Referrals was established to evaluate the Commission's programs in the area of recruitment and presented its recommendations;

- Following this, a special group responsible for the applications of the Task Force's recommendations was put in place;

- Our Post-Secondary Recruitment Program has also been modified following this evaluation;

Adaptation au nouvel environnement

- **Étude sur le recrutement et les présentations**

- En 1987, la Commission a procédé à une étude approfondie de ses activités de recrutement et de présentations;

- Cette étude comportait les initiatives suivantes: analyse des données démographiques sur le recrutement; entrevues avec des employés des directions du personnel pour évaluer leurs besoins; entrevues avec des étudiants pour discuter de leurs impressions sur la fonction publique fédérale et de leur intérêt à y faire carrière; entrevues avec les agents de recrutement pour examiner leur façon de concevoir leur role, leurs activités, ainsi que leurs difficultés à attirer des candidats qualifiés; entrevues avec des représentants des gouvernements étrangers et avec des organismes du secteur privé pour discuter de leurs méthodes de recrutement;

- Selon l'étude en question, la réduction des effectifs (et ses soi-disant répercussions sur la sécurite d'emploi et les possibilités de promotion) était un facteur déterminant dans la décision de beaucoup de jeunes de ne pas opter pour une carrière dans la fonction publique;

- Le secteur privé a embauché des candidats à un rythme plus rapide et de façon plus agressive que la fonction publique;

- Les campagnes organisées de recrutement pour des postes de niveau d'entrée se sont avérées plus efficaces que les procédés spéciaux, lorsqu'il était question d'attirer les candidats les plus prometteurs;

- Les méthodes de recrutement ne pouvaient rivaliser avec celles des autres grands employeurs.

Coping with the new environment

- X Enhanced recruitment strategy
- Renewed post-secondary recruitment program
- Rejuvenation initiatives

•Enhanced recruitment strategy

- identify needs (forecast and plan recruitment with depts)

- active recruitment:

~ integrated image and marketing
~improved liaison with educational institutions
~publicity for specialized and middle/senior jobs when high calibre candidates not in inventory

- better assessment of applicants to:

~ensure high quality referrals
~retain only high quality applicants

Adaptation au nouvel environnement

- Nouvelle stratégie de recrutement

X Programme renouvelé de recrutement postsecondaire

- Initiatives de rajeunissement des effectifs

Renouvellement du programme de recrutement postsecondaire

- La coordination du recrutement postsecondaire sera assurée à longueur d'année;

- Une nouvelle stratégie de mise en valeur a été élaborée afin de présenter une image plus dynamique des possibilités d'emploi dans la fonction publique pour inciter un plus grand nombre de diplomés à soumettre leur candidature;

- Une approche plus professionnelle et compétitive a permis de repenser le matériel de promotion comme les brochures, affiches, etc.;

- Les visites effectuées par les gestionnaires ministériels dans les campus permettent aux étudiants de se faire une meilleure idée des possibilités de carrière dans la fonction publique.

Coping with the new environment

- Enhanced recruitment strategy
- Renewed post-secondary recruitment program

X Rejuvenation initiatives

•Working group on Science and Technology Human Resource Management

- comprised of departments which are major users of scientists and engineers and also of central agency representatives established to co-ordinate human resource management;

- the group looks at ways to effectively manage the scientific community within government;

- elements of the strategy already in effect are:

  ~ provision of part-time employment after retirement
  ~ increased use of educational leave,
  ~ term employment for initial research appointments
  ~ use of developmental assignments.
  ~ examination of classification standards and compensation problems for Research Scientists.

•Special person year allocation for renewal and revitalization

- a special pool of person-years to allow departments increased flexibility in renewing and revitalizing the scientific community. (50 py last year, 75 this year and 50 next year)

LA MAIN-D'OEUVRE HAUTEMENT QUALIFIÉE DANS LES PAYS DE L'OCDE

GILLES JULIEN

VICE-PRÉSIDENT EXÉCUTIF

CRSNG

le 3 mai 1989

LA MAIN-D'OEUVRE HAUTEMENT QUALIFIÉE DANS LES PAYS DE L'OCDE

GILLES JULIEN

Dans ma présentation d'aujourd'hui j'aimerais d'abord vous sensibiliser à la structure de l'OCDE en mettant l'accent sur les comités et activités touchant les questions de main-d'oeuvre pour ensuite vous présenter très sommairement les conclusions de certaines études de l'OCDE dans le domaine et plus précisément de l'étude récente pilotée par le Dr Kavanagh et enfin vous faire part de la teneur et de l'orientation des activités et études à venir.

La plupart des personnes intéressées par des questions économiques connaissent bien cette organisation internationale de 24 pays membres qui s'appelle l'OCDE. Il y a peut être peu de gens cependant qui savent que l'organisation a été fondée en décembre 1960. Il y a encore moins de gens qui ont eu l'avantage de prendre connaissance de la convention signée par les pays membres en 1960 et plus particulièrement des articles 1 et 2. Je vous en fait la lecture parce que ceci me semble tout à fait approprié à ma présentation. À l'article 1 on lit: "l'organisation de coopération et de développement économiques a pour objectif de promouvoir des politiques visant:

a) à réaliser la plus forte expansion possible de l'économie et de l'emploi et une progression du niveau de vie dans les pays membres;

Article 2: en vue d'atteindre ces objectifs, les membres conviennent, tant individuellement que conjointement:

a) d'assurer l'utilisation efficace de leurs ressources économiques;

b) dans le domaine scientifique et technologique, d'assurer le développement de leurs ressources, d'encourager la recherche et de favoriser la formation professionnelle;

On aura sûrement remarqué à l'article 2b que l'OCDE considère d'abord la science et la technologie comme étant des éléments clés de la relance économique mais ensuite qu'à l'intérieur même de cet article, l'OCDE considère la recherche et la formation de main-d'oeuvre comme étant intrinsèquement reliées au développement scientifique, technologique et économique.

Afin de poursuivre ses activités, l'OCDE a mis sur pied un très grand nombre de comités où chaque pays membres est représenté. Je vous dispense de la liste des 27 comités qui existent dans le moment. Je me permet toutefois de vous souligner quatre comités qui

ont récemment abordé certaines questions relatives à la main-d'oeuvre en général et à la main-d'oeuvre en recherche plus particulièrement. Ces quatres comités sont:

1) le comité sur l'éducation
2) le comité sur l'industrie
3) le comité sur la main-d'oeuvre et les affaires sociales
4) le comité sur les politiques scientifiques et technologiques.

Qu'arrive-t-il des travaux et études de ces différents comités? J'imagine que tous connaîssent la réponse: ces études sont régulièrement publiées sous la forme de rapports ou de publications officielles de l'OCDE. J'entends déjà quelques chuchotements dans la salle de gens qui disent "oui, mais ces rapports où aboutissent-ils?" On est porté à croire que la plupart de ces rapports finissent sur des tablettes et accumulent de la poussière. Pourtant, les pays membres de l'OCDE ne cessent de se comparer les uns aux autres via ces rapports en les interprétant bien sûr mais en s'en servant afin d'influencer leur propre politique domestique. Le CRSNG n'est pas étranger à cette influence et il en est de même de beaucoup de collègues que je reconnais dans cette salle. Je suis conscient que dans le cadre de cette présentation il m'est impossible de vous faire une liste de tous ces rapports, même de ceux qui se rapportent à la question de main-d'oeuvre. Je me limiterai à vous parler de deux récents rapports et de porter à votre attention certaines conclusions qui me semblent relativement pertinentes aux délibérations d'aujour'hui.

À l'automne 1986, l'OCDE lançait le premier numéro de sa nouvelle revue intitulée Science, technologie et industrie. Le tout premier article publié dans cette revue s'intitule "Technologie et emploi". Il y a un autre article du même numéro qui s'intitule "Science, technologique et compétitivité". Je vous lis d'abord un extrait de ce dernier article sur la compétitivité. Il s'agit en fait du dernier paragraphe de la conclusion "Enfin, l'analyse présentée ici a souligné à plusieurs reprises l'importance du "capital humain" et la nécessité d'un effort permanent pour améliorer et développer l'enseignement à tous les niveaux. Aujourd'hui, la santé économique et le développement futur des pays membres dépendent dans une très large mesure de la capacité de leur système universitaire d'enseignement et de recherche, de former et de préparer les jeunes générations. Cette tâche doit être envisagée dans une perspective à long terme. En privilégiant un enseignement et une recherche scientifique adaptés à des impératifs économiques de court terme et à des bénéfices immédiats à une époque où tous les paramètres de l'activité économique subissent une mutation, on risque de compromettre la réalisation des impératifs de recherche et de formation à long terme. Ce sont pourtant ces derniers qui détermineront la capacité de faire face avec succès aux défis de demain."

Je reviens maintenant au premier article intitulé "Technologie et emploi", qui, à mon avis, projète une préoccupation croissante au niveau des pays membres de l'OCDE et cette préoccupation tourne autour de l'impact des technologies, spécialement les technologies nouvelles, sur l'emploi et la qualité de la main-d'oeuvre. Il était normal que suite à l'apparition de la vague de technologies nouvelles dont l'électronique, l'informatique, la télécommunication, les matériaux industriels, les technologies de conception et de fabrication et dans la biotechnologie, que les pays membres de l'OCDE examinent les retombées de ces technologies sur la main-d'oeuvre en place mais surtout sur la main-d'oeuvre requise pour demeurer économiquement compétitif. Il est reconnu que ces technologies peuvent collectivement être appliquées à presque tous les secteurs de l'économie depuis l'agriculture, les industries manufacturières, jusqu'aux services commerciaux comme le secteur bancaire, les assurances, le commerce de détail, les services publics comme l'éducation et la santé etc. Vous comprendrez donc que cette étude a couvert un spectre de préoccupations beaucoup plus vaste que celui qui nous préoccupe aujourd'hui, mais quand même pertinent.

La conclusion principale de l'étude est la suivante:
"Le changement technique n'a pas eu d'influence notable sur les niveaux nationaux de chômage et d'emploi et les taux de croissance économique ... alors qu'on prévoit une application plus étendue encore de la nouvelle technologie, on ne s'attend pas à ce qu'elle affecte sensiblement le niveau global de l'emploi et du chômage dans la décennie à venir. Les principaux effets porteront plutôt sur la nouvelle répartition de la main-d'oeuvre entre branche d'activité et service et entre profession. Chaque pays pourra, en partie, gagner ou perdre des emplois, selon la capacité de sa main-d'oeuvre à s'adapter au type changeant de demande d'emploi et selon qu'il devancera les autre pays ou se fera distancer dans l'introduction de technologie de pointe."

Un peu plus loin dans ce résumé on retrouve une conclusion que je juge très pertinente à notre séminaire d'aujourd'hui. Voici quelques extraits de cette conclusion: "Parmi les professions qui offrent les meilleurs perspectives de croissance de l'emploi, nombre d'entre elles exigent des niveaux de qualifications sensiblement plus élevés que les professions en déclin. Ces emplois plus qualifiés englobent les scientifiques et ingénieurs, les informaticiens, les techniciens et le personnel des services et les directeurs de recherche-développement, ingénieurs et cadres de production - tous devant posséder des compétences dans le domaine des technologies nouvelles. Par ailleurs, les besoins en main-d'oeuvre semi-qualifiée et non qualifiée vont probablement diminuer, surtout pour les opérateurs sur machines, les monteurs et les ouvriers qualifiés traditionnels. Pour toutes ces raisons, les emplois créés ne peuvent pas être occupés directement par ceux dont les postes ont été supprimés; on ne sait pas exactement dans quelle mesure le recyclage pourrait permettre de combler ce manque".[1]

[1] STI revue (OCDE) No1 automne 1986, "Technologie et emploi"

Une autre publication de l'OCDE, celle-là beaucoup plus récente, recommande certains changements dans les systèmes éducatifs et de perfectionnement de la main-d'oeuvre afin de pouvoir répondre aux besoins des employeurs face aux nouvelles technologies. Cette publication de l'OCDE parut en 1988, s'intitule "Nouvelle technologie: une stratégie socio-économique pour les années 90".

Deux recommandations sont très pertinentes à notre séminaire. La première de ces recommandations porte sur l'intégration des systèmes et facteurs reliés à la recherche et développement et se lit comme suit: "L'innovation technologique et le changement social doivent être considérés comme un processus intégré et gérés dans cette optique. La diffusion et la gestion de l'innovation doivent faire partie intégrante de toute politique technologique. Les politiques relatives au changement technologique doivent déborder le seul domaine de la R-D pour faire une place importante au marché du travail, au système d'enseignement, aux entreprises et à divers autres aspects sociaux que notre rapport met en lumière."[1]

Une deuxième recommandation vise à rendre les systèmes éducatifs des pays membres plus proactifs et mieux axés sur les véritables besoins de la société d'aujourd'hui: "Le changement technologique ne peut être réalisé s'il n'est pas accompagné, voire précédé, d'une transformation du système d'enseignement et de formation en vue de répondre à la nécessité de disposer d'une main-d'oeuvre plus instruite et mieux qualifiée. Il faut que la formation soit dispensée selon des modalités d'un caractère plus souple, aussi bien dans les entreprises que dans l'enseignement supérieur. Les études secondaires et supérieures très générales qu'effectueront un grand nombre de jeunes devront être complétées par une formation pour adultes plus spécialisée qui sera assurée tout au long de la vie professionnelle, tantôt dans l'industrie, tantôt dans les établissements d'enseignement, tantôt dans les deux à la fois. Les enseignants auront besoin d'un recyclage fréquent. Les méthodes éducatives et la pédagogie doivent encore être développées de manière à favoriser chez les jeunes l'esprit d'initiative, la créativité et le sens des responsabilités en vue de mieux les préparer aux nouvelles conditions du monde du travail. Ces efforts représenteront des coûts non négligeables. Les pays membres ont des pratiques diverses en matière de financement, mais nous pensons que, par principe, l'employeur - et pas seulement l'état - devrait assumer une responsabilité importante dans le recyclage destiné à apprendre aux salariés à utiliser les équipements et les procédés nouveaux."[1]

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[1] Nouvelles technologies, une stratégie socio-économique pour les années 90, OCDE Paris 1988

Compte tenu de l'importance des questions soulevées par les études que je viens de mentionner, il n'est pas étonnant que l'OCDE ait décidé d'entreprendre une étude plus détaillée d'un aspect plus ciblé des questions reliées aux ressources humaines, celui du personnel de recherche. Cet intérêt s'est vite propagé aux pays membres qui tous font face à des problèmes majeurs tant au niveau de la prédiction de l'offre et de la demande en personnel de recherche qu'au niveau du recrutement de personnel adéquatement formé et qualifié dont les trois secteurs de recherches ont besoin. C'est au cours de cette étude que le Dr Robert Kavanagh a eu la possibilité d'examiner les mécanismes mis sur pied par les pays membres pour prédire l'offre et la demande en personnel de recherche.

Voici les grandes conclusions du rapport Kavanagh: "Les enquêtes menées pour la préparation du rapport ont confirmé que la planification de la main-d'oeuvre est un problème extrêmement complexe. Toutefois, la grande majorité des pays membres estiment très important de disposer d'une offre suffisante de chercheurs".

"La prévision de l'offre est peut-être une science moins inexacte que la prévision de la demande. En général, les pays membres utilisent des méthodes voisines, mais en dépit de quelques ressemblances, les différences marquées observées entre les pays signifient que les techniques ne sont pas facilement transférables d'un pays à l'autre."

"En fait si les modèles de prévision de l'offre ont leurs limites en ce qu'ils ne permettent pas de produire des données exactes, ils permettent de prévoir des tendances avec un degré acceptable de confiance, et montrent de quel façon certaines mesures pourraient agir sur l'offre afin d'établir des stratégies qui pourraient être mises en oeuvre pour l'accroître."

"La prévision de la demande est à coup sûr une science inexacte et les techniques les plus complexes elles-mêmes n'ont pas permis d'aboutir à des prévisions exactes. C'est pourquoi certains pays membres sont très sceptiques. Les prévisions de la demande sont très influencées par la conjoncture économique d'un pays qui à son tour dépend de la situation économique d'autres pays."

"Les pays membres utilisent une variété de techniques pour améliorer l'adéquation entre l'offre et la demande." Entre autres, les liens entre l'université et les industries et la participation accrue de l'industrie dans l'orientation des curriculums universitaires devient un facteur important. "Les informations communiquées par presque tous les pays membres soulignent généralement qu'il importe au plus haut point d'encourager les femmes à s'orienter vers les sciences et la technologie. On constate également que les diverses déclarations de politique et les

programmes des pays membres attachent relativement peu d'importance à la qualité, en ce qu'elle se distingue de la quantité." Une augmentation du nombre à tout prix peut conduire à une diminution des standards de qualité. "Les problèmes d'inadéquation entre l'offre et la demande passent par un phénomène de variation cyclique de la population d'âge universitaire dont la période est d'environ 25 à 30 ans. Pour stabiliser dans une certaine mesure l'offre de chercheurs, il faut trouver des moyens d'atténuer les conséquences de cette périodicité. Le problème s'est posé d'une façon aigue dans le secteur universitaire où la mobilité est nettement moins grande que disons dans le secteur privé.

Comme on le voit le problème en est donc un d'adéquation, tant qualitative que quantitative, des ressources humaines dont nous disposons pour faire de la recherche. L'évolution que nous observons tient pour une part à l'importance croissante des possibilités qu'offre l'industrie aux chercheurs, et à l'exode des chercheurs universitaires vers l'industrie qui leur fait des offres peut-être plus intéressantes. À ceci s'ajoute l'impression générale que la profession de chercheur universitaire a marqué un recul tant sur le plan de sa position sociale que sur celui du prestige. Dans plusieurs pays dont le Canada, le peu de fonds consacré à la recherche universitaire décourage les étudiants et il est donc fort concevable qu'à l'avenir les chercheurs soient de plus en plus difficiles à recruter et qu'ils viennent même à manquer.

Il n'est pas rare que des études de l'OCDE se terminent à l'étape de recommandations laissant aux pays membres le soin de les mettre en route en tenant compte de considérations domestiques. Dans le cas du personnel de recherche, les solutions aux problèmes identifiés sont tellement complexes que l'OCDE a convenu d'encourager les pays membres à continuer d'échanger les résultats de leurs efforts pour combler leurs lacunes en personnel. C'est ainsi que le groupe sur la recherche scientifique et universitaire examinera bientôt les démarches prises par les pays membres pour assurer le remplacement du corps professoral universitaire. Concurremment, le groupe examinera les programmes mis en place pour encourager d'avantage de femmes à entrer dans les carrières de science et de technologie. Finalement, le comité sur les Politiques scientifiques et technologiques de l'OCDE à récemment décidé d'accorder la plus haute priorité à ses activités centrées sur les relations entre les universités et les industries, relations qui non seulement permettent un transfert efficace des technologies mais qui améliorent l'adéquation entre l'offre et la demande en personnel de recherche.

Je ne voudrais pas terminer cet exposé sans remercier le Dr Robert Kavanagh non seulement pour avoir organisé ce séminaire mais surtout pour m'avoir offert cette tribune alors qu'il aurait pu lui-même avec compétence, éloquence et concision vous entretenir de son expérience à l'OCDE.

Speech

BNR

BUILDING A TECHNOLOGY CULTURE:
Business' future needs for highly qualified scientists and engineers

REMARKS BY

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TO A SEMINAR SPONSORED BY
THE NATURAL SCIENCES AND ENGINEERING
RESEARCH COUNCIL OF CANADA

OTTAWA, ONTARIO
MAY 3, 1989

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T.M. (Tom) Hennebury
Vice-president, Human Resources
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Bell-Northern Research Limited
to a seminar sponsored by
The Natural Sciences and Engineering
Research Council of Canada
Ottawa, Ontario
May 3, 1989

Building a technology culture: Business' future needs for highly-qualified scientists and engineers

Ladies and gentlemen: When Bob Kavanagh asked me to participate in this seminar -- to talk about business' future requirements for highly qualified engineers and scientists -- my first instinct was to beg off.

It wasn't the topic that bothered me. It's one of the most important issues facing our country. And it wasn't the company. This is certainly a high-power forum.

But what nearly stopped me from speaking was a growing sense of frustration that I feel when it comes to discussions dealing with education, innovation, and industry. Because I'm worried there is little I can say that should be news to anyone concerned with Canada's economic future.

Yes, Canadian business will soon be facing a shortage of highly qualified scientists and engineers. It will be a shortage in the volume of technologists that our universities produce, in the skills available to help business meet the needs of 21st Century industrial competition.

But what really bothers me is the lack of true alarm -- in terms of public consensus or hard-edged political initiatives -- about the situation. Education has become like the issue of Canadian R&D spending: a constant source of newspaper copy, business speeches, and campaign platforms, but no truly decisive action.

Maybe I'm being too pessimistic. Perhaps there's some magic alternative to scientist-driven R&D and industrial innovation that will allow the Canadian economy to compete successfully in a global environment of accelerating competition.

If the press could get their hands on that secret strategy, you'd really have a front page "scoop." But the fact is, such an alternative just doesn't exist.

And this means, unless we can achieve a dramatic shift in our national culture to emphasize science and technology education, that Canada could rapidly find itself becoming a member of the "Fourth World." In other words, we could devolve from a nation of reasonable prosperity, to one on the economic periphery, unable to sustain an acceptable standard of living.

Before I move into my talk, there's a basic point I want to emphasize. It's not government that deserves the primary blame for any national dilemmas we face over education, and science education in particular. There's no point blaming the actors for a bad script.

The real scenario for Canadian technological development and science education is being written by business and the public at large. That's what happens in a democracy.

How can we blame government for not recognizing the importance of strengthening engineering education when (according to the Ontario Premier's Council) 70 percent of manufacturing firms in this province don't have a single engineer on staff?

How can we blame government for not moving to expand our supply of scientists and researchers when, of eight major OECD nations (the U.S., Japan, Germany, France, Italy, Sweden, the Netherlands, and Canada), ours is the only country where private sector R&D is lower than that spent by government?

And, most fundamentally, how can we blame government for not allocating more of its strained resources to science education, in the absence of any real national demand for action. It's frightening that so many Canadians seem more vocal about maintaining social safety nets -- including the costly infrastructure needed for "universality" -- than they are about investing in the science education that will help us fish in new economic waters.

It's this view that sets the framework for my remarks this afternoon. And I'll be focusing on two basic issues.

• First, I'll share my perspective on the evolving demand/supply equation that is defining business' requirements for highly qualified scientists and engineers. My key point here is that we are facing a decrease in the supply of Bachelor and advanced graduates, just at a time when there is good reason to anticipate a significant increase in demand.

• Then I'll address some of the action items that are essential to meet the supply challenge Canada will be confronting. In particular, I'll emphasize the need to work at all levels of the education system -- starting at the primary school level -- to build a national science and technology culture. Unless we can do that, I believe, all other initiatives will have only marginal success.

So let's start with a brief review of the demand/supply equation.

An excellent case can be made that the real problem facing Canadian industry today is not with the supply of scientific personnel, but rather with the lack of demand for them.

Canada has the lowest percentage of scientists and engineers in its labor force of any major OECD nation. As reported in a recent C.D. Howe Institute study, our country deploys only 30 R&D scientists and engineers for each 1,000 industrial workers. By contrast, the U.S. had 65 R&D scientists and engineers per 1,000 workers; Japan had 62; Germany stood at 49; the U.K. at 43; and France at 41 per 1,000 employees.

To me, it is no coincidence -- given this weak demand for scientific personnel -- that Canada has an equally dismal record in R&D activity, and in industrial productivity.

It's been well documented that Canada ranks near the bottom of industrial nations in terms of national expenditure on R&D as a percentage of GDP. This has become a fact of national life, even more certain than the failure of Toronto's Maple Leafs to make the Stanley Cup play-offs.

What too many Canadians fail to recognize is that R&D is not just an issue of developing new products. At companies like Northern Telecom, a portion of R&D investment goes to process development, to enhance its competitive productivity in support of existing products.

However, this seems to be an activity where such firms are the exception, not the rule. That's why I wasn't surprised to learn that, according to a report last year from the U.S. Department of Labor Statistics, Canada's manufacturing sector recorded the slowest productivity growth among the 12 major industrialized nations between 1977 and 1986. Indeed, in 1986, Canada was the only one of the 12 to experience a decline in productivity.

There are many factors involved in productivity performance. But one of the most critical is the ability to apply new technologies and develop innovative processes -- activities that simply cannot take place effectively or cost-efficiently when companies will not invest in the engineers and scientists needed to identify and implement them.

It's clear, then, that Canadian business' appetite for innovation -- and for the scientific personnel who make it possible -- lags behind many of our competitor nations. And further evidence of our failure to become a technology-oriented culture can be found in the proportion of students who select engineering and applied science disciplines.

I understand that just some nine percent of undergraduate degrees are in these fields -- just a slight increase over the 6.5 percent figure of nearly 20 years ago. At the graduate level, some 30 percent of all degrees came in engineering and science -- representing a harsh decrease from the 37-percent level of 1970.

These statistics would be grounds enough for national concern in a world where economies are increasingly technology-driven. But the problem is being drastically compounded by the impact of demographic trends -- the decline in the student-age population -- and university enrollment patterns.

Undergraduate enrollment in engineering has already started to decline. For example, in electrical engineering -- a key discipline for the high-technology sector -- just under 1,800 degrees will be granted this year, compared to 2,600 in 1987. And in computer science, the trend is even more distinct: from total enrollment of 12,500 in 1984, to fewer than 8,000 last year -- a 36-percent drop in only four years.

Again, this problem will not be news to this forum. It has been well documented, especially by NSERC and Bob Kavanagh.

What I want to turn to, then, is the implications this situation has for business -- all business, including the service sector, and not just high-tech firms.

To begin, the issue is not whether a shortfall of qualified personnel currently exists. In BNR's experience -- and judging from conversations with other high-tech employers -- we are having reasonable success at obtaining the volume and quality of graduates we require.

I must point out, however, that BNR -- and companies we're familiar with -- work hard at achieving this success. For example, it was our need to ensure a constant supply of high-quality new-grad hires that was one of the key reasons we established our University Interactions Program.

But if supply and demand are in relative balance right now, this will not hold true in the near future. Not only is the supply shrinking, but there should also be a boost in demand -- unless Canadian companies are willing to accept diminished profitability and shrinking markets.

The primary driving force for this growth in demand will be the reality of increased competition. In particular, Canadian business is facing the challenge -- as well as the opportunity -- brought about by the Free Trade Agreement with the United States. But this is just part of a broader world trend to more open markets and greater global competition, as witness Europe's rapid move towards establishing a unified market in 1992.

This challenge of increased competition demands that business acquire a new commitment to productivity and innovation. Let me again cite Northern Telecom and BNR as an example.

We estimate that some 80 percent of Northern's revenues -- $5.4 billion U.S. last year -- can be attributed to BNR-developed systems and product features that did not exist five years ago. If we were not committed to delivering customer value through R&D -- with Northern investing more than 13 percent of revenues -- we would not be a world-leader in our industry: we probably wouldn't even be a winner in Canada.

It's not just out of pride and familiarity that I use Northern Telecom and BNR as an example of a competition-oriented approach to science and innovation. It leads me into the issue of information technology in general -- which is both a source of opportunity for Canada, and also a driving force that could push our demands for science-trained students higher.

In Canada, information technology is a $28-billion business -- including exports of nearly $6 billion (and imports of $4.3 billion). As an industry, it has consistently outperformed the economy as a whole, and in 1987 employed 220,000 people -- an increase of 12,000 over the year before.

There are several points involved here. To begin, information technology is a key productivity tool for virtually all business sectors -- services as well as manufacturing. No wonder that as a proportion of world trade, data processing devices (only one aspect of this technology) jumped from 20th to 7th place between 1973 and 1983.

If Canada is to expand its performance in this key growth sector, a continuing supply of highly qualified scientists and engineers is an essential ingredient. This one sector spent $1.4 billion in R&D in Canada in 1987 -- equivalent to 40-percent of Canada's entire private R&D effort.

But there's another way that information technology can impact the demand for science and engineering graduates. Because those businesses that want to get the greatest competitive advantage from information systems -- both telecommunications, computers, and robotics -- will need to increase their own in-house specialists in this area.

The reason is simple. Any productivity tool that you use in exactly the same fashion as your competitor, provides no comparative advantage. It's a zero-sum game: at the very best, you merely stay equal with your opponent.

Companies that are committed to competitive success, are those that are willing to develop their own particular applications based on these tools -- applications that provide unique benefits. And the Canadian firms willing to do that, will require increases in their technological personnel.

So far, I've touched on two forces -- global competition, and the growth in information technology -- that I believe could spur Canada's demand for technologically educated employees. But both these forces depend on Canada acquiring a new commitment to innovation and technology.

But there are other forces affecting the demand scenario that have nothing to do with business' will to compete. The most significant of these is the growing demand for engineers and scientists occurring outside Canada.

At an OECD workshop in Paris on research manpower last winter, we learned that Japan expects an under-supply of 7,000 key research personnel in science and engineering by the year 2000. In Spain, where the current number of researchers per 10,000 workers is one-half the OECD average, they have established a national plan to reach the average by 1997. And there is also the United States, where the supply of university engineering and science graduates faces the same demographic shortfalls as we are confronting in Canada.

To me, this clearly signals that there will be increasing global competition for qualified research personnel -- especially at the post-graduate level, and for experienced hires. And there is little doubt that the students at leading-edge Canadian universities will become ever more desirable targets for foreign recruiters.

The last demand/supply force I would like to mention involves a social as well as economic agenda. This deals with the commitment of Canadian society to employment equity, for women in particular.

You are all familiar, I'm sure, with the under-representation of women in engineering and applied science. In 1985, they were only 12 percent of undergraduates in these fields, and less than 8 percent of Doctoral candidates.

These figures carry significant implications. Most importantly, they mean that -- at a time when Canada faces the greatest economic challenge in its history -- we are failing to access a vast pool of potential talent. They also suggest a growing dilemma for Canadian companies that -- as a result of their own commitment, or due to legislative pressures -- seek to strongly boost the representation of women in their engineering and scientific staff.

These, then, are some of the challenges Canadian business faces in terms of the supply and demand for highly qualified scientists and engineers. It's a problem that deserves strong and immediate action on a national front, if we are to seize the opportunities for economic development and prosperity in the high-tech Information Age.

So now, I'd like to share some prescriptions for progress, drawing on the experience of BNR and Northern Telecom (which combined represent the largest private-sector source of employment for engineers in Canada).

My starting recommendation is as obvious as the statistics I've discussed.

Our nation must recognize the strategic importance of education -- and of science and technology education in particular. We need to make the hard public choices regarding funding and priorities that truly position education (as the Japanese say) as "the key that opens the lock."

I was recently in a meeting with Dr. Doug Wright, principal of the University of Waterloo, and was intrigued by some data he had assembled.

It showed that the average expenditure per university student (under- and post-graduate) in Ontario -- involving both government funding, and tuition fees -- is currently $6,500, of which $5,250 is government grants. (Incidentally, that $6,500 compares with a $6,200 expenditure for secondary school students.)

In the U.S., by comparison, the average university revenue per student from state and local grants alone is nearly $8,700 (in Canadian funds), and that doesn't include their significantly higher tuition fees. In the state of Alabama alone, which is not one of your economically advantaged areas, state and local support per university student averaged $11,180.

For me, the message is clear. We are underfunding our institutions of advanced education at a time when the role they have to play has never been more crucial.

I was also fascinated by Dr. Wright's views on the disadvantages -- or disincentives -- confronting Canadian post-grad research assistants in the sciences, compared with America and Europe.

He pointed out that such graduate work at most U.S. universities does not provide excessive stipends -- generally comparable with those available to Canadian post-grads. However, students there tend to have a lower teaching load, and often have access to first-class facilities and internationally recognized professors. And for foreign students, there is the added appeal of virtual guaranteed landed-immigrant status.

In Europe, Dr. Wright said, there are different factors acting as an incentive to post-graduate study. Graduate stipends can be considerably greater than in North America (up to $30,000 a year in France). Not only that, students generally do not have to undertake a teaching load, and can often go from a Bachelor degree to completing their Doctorate in three years.

But Canada seems to have the worst of both systems.

Graduate stipends and research fellowships are low enough that students are virtually compelled to accept teaching loads to help support themselves (and their families). The time required to reach Doctorate status is generally five years or more -- time when the graduate student could be earning an above average wage in industry. And for foreign students, unless they receive special exemption, graduation generally means a departure from Canada -- a loss of valuable skills that we have invested in, but are not available to Canadian industry.

Increased funding -- including that available through NSERC for graduate research -- is only part of the solution. And it faces obvious political difficulties, given the federal government's long-overdue commitment to fiscal restraint to bring our horrendous deficit under control. This leads me to another fundamental action item that Canadian business people and science educators must apply our imaginations and resources to.

It's vital that we begin to build a "science culture" in Canada -- a culture that starts right at the primary school level, and enthuses students with the possibilities and rewards of engineering and science careers.

There are already a number of valuable initiatives taking place in Canada.

There is the Shad Valley summer work-study program for high school science students. It's a program that BNR and Northern Telecom both support -- but which is still struggling to find sufficient corporate sponsors to accommodate all the qualified students who apply.

We are also supporting a truly innovative program initiated by the Queen's University student engineering society. Called Science Quest, it offers week-long summer activity programs to primary school students, exposing them to the fun and intrigue of science.

Another leading-edge initiative sponsored by Northern Telecom is its annual national education awards and institute, which brings together top teachers at all education levels who have been involved in expanding the students' use of and education in information technology.

There is a BNR activity I also want to briefly highlight. It's a pilot program we call Partners in Education, and it involves establishing a special relationship with a nearby high-school, Earl of March Secondary School.

In this program -- which somewhat resembles the Adopt-a-school programs to be found in the U.S. -- we work with the high school to expand faculty and student understanding of the nature and challenges of our business. In turn, we have acquired a better fix on the directions and challenges involved in contemporary high school education.

This is not intended to be a commercial for the Northern Telecom/BNR corporate family. The point I am really trying to make it that we are committed to acting on the recognition that education -- and science education especially -- is of strategic importance to our future.

That is why we have a focused group of people in my department who are dedicated full-time to managing our University Interactions Program -- and this does not include a separate team of specialists in university undergraduate recruitment.

And it is our recognition of the need to expand our involvement in education beyond the university sector, that has led to the addition of a high-school liaison specialist in that Interaction team. In fact, this role is being handled by an Earl of March faculty member who has been seconded to BNR (at our expense) for the two-year Partners pilot program.

The Partners program is already expanding. Two other schools in the Carleton region have corporate partners, including Hewlett-Packard.

Through such interaction, we are helping to build a vital tool to ensure that the public education system and business understand and support each other better in meeting the needs of a changing world environment.

Again, I want to emphasize that such initiatives do not make us unique among Canadian business. There are other leading edge high-tech firms who are also committed to the cause of education. These include Hewlett-Packard (Canada), with its Calculator Awards Program, which honors top university students entering their final year in science, computer science, or business; and Xerox Canada Inc., which sponsors the Marshall McLuhan Distinguished Teachers awards.

But while there are companies which champion the cause of education, it is also clear that the great majority of Canadian firms either have little direct involvement -- or else limit their support to straight financial contributions in response to university capital campaigns.

Such "charity" style support is not the answer. It may help bandage the system, but it doesn't do a thing to change the national culture that undervalues education and science.

What we need is real involvement -- and a commitment to build a critical mass of public awareness and concern about the abilities and status of Canada's education system.

In my mind, it's time we moved on a cross-industry front to build a new dimension of national consciousness and support for science education -- both in the public at large, and among students.

We need to use the tools of publicity and advocacy with the consistency and fervor that were so successful at changing public opinion on smoking, and on drunken driving

And maybe we need to pull together a consortium -- companies like BNR, agencies like NSERC, institutions like the Youth Science Foundation, and associations like the Professional Engineers of Ontario -- to explore how to fund and create new promotional vehicles and activities that would make careers in engineering and science something that's top-of-mind for primary and high-school students. Right here and now, I'll gladly commit to making BNR personnel available to work on such an undertaking.

Ladies and gentlemen, some of you may have been expecting a more diagramed, process-oriented commentary on post-graduate science funding, program administration, and university-business research links. But this is ground that BNR has covered at many forums, and I felt it was time to shift the focus into broader, more fundamental dimensions.

Yes, in BNR's view it is essential to build a true relationship with universities if any company intends to meet its goals for the supply of qualified engineers and scientists. And I'd be glad to share aspects of our University Interactions Program -- which includes active participation with NSERC in funding research chairs at various Canadian universities.

But the real issue we face is not one of strengthening the programs of those companies who are already committed to such endeavor. It's time to move beyond preaching to the converted.

The real battle we face is to change the attitudes and opinions of the multitude of Canadians -- especially employers, and the youngsters themselves -- so that they recognize science education as a critical source of individual and corporate opportunity.

That's the bottom-line agenda we face. Unless we can boost the participation rate of students in the sciences and engineering, then all the increases in funding and development of centers of excellence will do little more than slow an inevitable economic and scientific decline.

We face a clear choice. We can either be a culture committed to innovation and economic success -- or we can be a growing source of opportunity for our competitors. We can create wealth by being a seller of ideas and science-based products and services, or we can pay the price to support other nations' science leadership.

But if we're going to make the right choice, we can't look to government alone. It can only be an enabler, never a real initiator. That responsibility best belongs to business, and it's the Canadian business community that we must sign up.

I look forward to any questions you may have, but even more, I look forward to your views on this challenge, and how we can build the national science culture that Canada's future so desperately needs.

The Capacity of Canada's Universities to Educate Highly Qualified Scientists and Engineers

notes for an address to a conference on

Canada's Future Requirements for
Highly Qualified Scientists and Engineers

by

Arnold Naimark
President, University of Manitoba

Sponsored by the NSERC
May 3, 1989

Chateau Laurier Hotel
Ottawa, Ontario

The Capacity of Canada's Universities to Train Highly Qualified Scientists and Engineers

by
Arnold Naimark

ABSTRACT

After nearly two decades of retrenchment Canada's universities have been left with a weakened infrastructure for the support of research and graduate training. As a result of inadequate funding, deficiencies have appeared in direct graduate student support, the level of extramural research support, the complement of faculty supervisors, equipment, physical plant and academic support services. Each of these resource inputs may be a factor limiting the capacity for graduate training under certain circumstances; but their relative importance varies with time, place and discipline.

At present the most important limiting factors are graduate student support, project support and equipment. Once deficiencies in these inputs are remedied the latent capacity for graduate training will have been exhausted and further increases in the supply of scientists and engineers with graduate degrees will depend on expanding the complement of faculty supervisors and the size of the physical plant. The demography of the professoriate in Canadian universities poses special challenges for maintaining the continuity of development in research and graduate training.

A key strategic question facing universities, industry and government is whether the current system of graduate training of scientists and engineers is optimum for the purposes of industry, or alternatively, more differentiated systems are required. Finding the answer to this and many other questions surrounding the need for, and supply of, highly qualified scientists and engineers in Canadian industry will require some hard thinking. Increasing the output of such personnel by Canadian universities will require some hard cash.

Introduction

The general premise underlying the notion that universities should be training more highly qualified scientists and engineers is, to paraphrase Robert Kavanagh, as follows: scientists and engineers with master's and doctoral degrees will be needed in increasing numbers to "capitalize on the results of...fundamental research by the invention, development and production of new devices and processes" that can be profitably exploited by Canadian industry, in international competition, thereby enhancing Canada's future economic well being.[1]

The validity of this premise rests on demonstrating that the supply of master's and doctoral graduates in science and engineering is indeed a dominant and limiting input factor in industrial competitiveness rather than being an outcome. I am grateful, that for the purpose of my presentation, I can ignore this issue and take it as a given that increasing the output of scientists and engineers with graduate degrees from Canadian universities is a good thing to do.

My task is to provide an assessment of the current capacity of Canada's universities to produce such highly qualified personnel and to indicate what steps might be taken to enhance their capacity to do so in the future. Let me begin by outlining very briefly the historical evolution of the present state of Canadian universities.

1.Kavanagh, R.J. (1988) Increasing the Supply of R and D Engineers: The Role of NSERC. 6th Canadian Conference on Engineering Education

The Historical Context

Prior to the Second World War Canadian universities were small and selective. Total enrolment was about 35,000 students the majority of whom were urban, upper middle class males. Research and graduate studies were poorly developed so that most graduates seeking advanced study went abroad. In 1935 only 30 doctorates were awarded by Canadian universities. Returning war veterans, interested as they were in both education and procreation, not only crowded the universities in their day but produced the baby boom generation which ultimately would transform many aspects of Canadian society including its universities.

In the post-Sputnik enthusiasm for science and technology and with baby boomers swelling the ranks of high school leavers, universities became the favored instrument for promoting social and economic development. The late '50s and early '60s were the heyday of university expansion. New universities were established and old ones expanded to accommodate huge increases in enrolment. In addition to becoming larger, universities became more diverse as they responded to pressures to introduce many new programs.

In the beginning governments were willing financiers of the boom in higher education and soon became the dominant source of university revenues. Not only did general operating grants to universities from provincial governments grow rapidly, project-specific grants from the

federal research granting agencies also grew substantially as the federal government increased its financial appropriations for the support of university based research. An implicit social contract was established between the two levels of government insofar as research and advanced training was concerned. The provinces would support the infrastructure for research, the indirect costs, while the federal government and other non-governmental agencies would support the direct costs. I will say more about this later.

By the early 1970s the boom came to an end. For reasons which it would take too long to explain the priority of universities in the eyes of government began to dwindle. This resulted in a decline in the rate of growth in university revenues. Then came the oil crisis and rapid increase in the rate of inflation. Soon revenue growth fell below the rate of cost increases and the purchasing power of university budgets began to decline. Investment in plant and equipment was sharply curtailed not only for fiscal reasons but also because government planners had predicted that a sharp decline in enrolment would take place in the 1980s.

In short, in the 1970s, restraint and retrenchment became the dominant theme. Staffing levels declined and turnover of academic staff slowed as openings for new faculty dried up. Plant and equipment began to deteriorate, library acquisitions were curtailed and many services were discontinued. In the 1980s grants to universities have on the whole increased sufficiently to halt the overall decline in

purchasing power but this was offset by the fact that enrolment did not decline as predicted but instead increased sharply to new record levels. Thus the purchasing power per student served continued its seemingly inexorable decline.

In coping with prolonged restraint and retrenchment universities have been forced to make difficult choices in dealing with competing claims on their resources. Non-academic areas were cut back most sharply in order to sustain accessibility to academic programs, but the reduction in support services had among its effects the weakening of the infrastructure for research and advanced study.

It is not surprising that under the stress of constrained resources in the face of growing demands, the fundamental weakness in the current political framework for the support of higher education would become evident. For example, in recent years the federal government decided to increase the support for university-based research through certain targetted programs but it also restrained transfer payments to the provinces, which in turn prompted the provinces to restrain operating grants to the universities thereby weakening their ability to provide indirect support for research. This debilitating lack of harmonization of federal and provincial policies is also evident in the areas of student aid, foreign students and skills training.

The Current Context

Notwithstanding the difficulties of the past decade and a half Canadian universities have demonstrated remarkable resilience and an ability to meet challenges successfully if given adequate support. As evidence for this contention consider that:

- in 1935 there were 35,000 students in Canadian universities, now there are nearly 500,000
- in 1940, 40 Ph.D's were awarded, by 1985 the number had increased to 2000
- a generation ago we had to recruit faculty from abroad because we hadn't developed expertise in Canada but now we can call upon well-trained and talented Canadians to fill key posts in our universities
- higher education was once mainly the prerogative of an economic and social elite. Today we can be proud of having one of the most accessible university systems in the world
- Canadian universities are world leaders in the field of distance education and major players in Third World development
- effective linkages are being formed between universities and industry
- curriculum reform, development of specialized centres and institutes for advanced study and research, initiation of special access programs for disadvantaged groups and non-traditional learners, and many other developments, bespeak a

vibrant, albeit too often a latent, innovative thrust in Canada's universities.

The Capacity of Existing Programs in Science and Engineering

In examining the current capacity of Canadian universities to produce scientists and engineers with graduate qualifications there are at least the following factors to be considered:

* the size of the pool of potential graduate students

* the availability of funds to provide graduate student stipends in sufficient number and value

* the availability of faculty supervisors

* the level of research funding available to faculty supervisors

* the availability of research equipment

* the institutional infrastructure for research and graduate training

Before attempting an evaluation of these factors let me stress that their relative importance varies considerably from province to province, from institution to institution and from field to field. It also varies according to whether one is considering the capacity of long-established programs or of newly emerging fields. Given this

variability and the fact that there is at present no comprehensive database upon which to make reliable quantitative assessments I shall perforce only be able to offer qualitative, or at best semi-quantitative observations about the factors determining the capacity of Canadian graduate programs.

The Pool of Potential Graduate Students

If one defines the pool of potential graduate students as all of those Canadians (citizens or permanent residents) with appropriate qualifications in science and engineering who apply for admission to graduate programs, or who would do so if the conditions were favorable, then I believe it is safe to say that the size of the potential applicant pool is not, for now at least, a limiting factor in increasing the supply of graduate scientists and engineers. I support the views expressed by Mr. Fechter this morning; namely, that the continuation rate from undergraduate to postgraduate study will be a more important focus for policy intervention than will the size of the applicant pool. If, however, one defines the potential applicant pool more narrowly as those who apply for admission under current conditions then the size of the applicant pool is clearly a limiting factor in some fields and any expansion in pool size would require a change in conditions. Such changes might be fortuitous (the employment market for engineers softens so that more of them consider pursuing advanced training) or they might be deliberately induced by increasing the incentives for pursuing higher qualifications.

Much has already been said about the challenge of increasing the number of women, and others from under-represented groups, in the pool of potential graduate trainees - and I will not pursue the matter further here.

Graduate Student Stipends

There seems to be little question that the availability of graduate student stipends in sufficient number and value is now one of the most important limiting factors in expanding the supply of graduate students. Indeed informal soundings suggest to me that the numbers of graduate students in current programs could be increased substantially (perhaps as much as doubled in certain areas) without changes in other factors if stipendiary support were adequate.

Graduate student stipends now come from several sources: intramural scholarships and teaching assistantships, extramural scholarships (from granting agencies, foundations, and private sponsors) and the research grants of their supervisors. Some provincial governments have established substantial programs of graduate student support, others have not.

One of the notable effects of retrenchment in the support of research is on the ability to provide stipendiary support for graduate students. Thus when the base budgets of the research granting councils are reduced in real terms and the effective level of

research grants declines, researchers will understandably protect their basic operations at the expense, **inter alia**, of graduate stipend provisions. Similarly when universities are forced by funding restraint to reduce the infrastructure support for research, increased costs are borne by research grants thereby squeezing out the support for graduate students.

One final point related to graduate student stipends has to do with the need for flexibility. If one wishes to stimulate expansion in the supply of graduate students in certain fields where the competition with private industry is intense then it will be necessary to provide substantially higher stipends in certain fields of graduate study than in others and to allow flexibility in limits attached to supplementary sources of income.

Availability of Faculty Supervisors

The essential unit in graduate training is the faculty supervisor-graduate student diad. An adequate supply of highly skilled faculty supervisors is the **sine quae non** of the resource inputs required to expand the output of scientists and engineers with graduate training of high quality. I referred earlier to the effects of prolonged retrenchment on the ability of universities to recruit new faculty and provide for adequate levels of faculty turnover and renewal. Such turnover and renewal is important for at least two reasons. First, it is one of the most important ways in which new

lines of research and new kinds of expertise are introduced into established departments. Second, while not inevitably true, it is nonetheless common for the life cycle of the typical faculty member to be characterized by some diminution in scale and intensity of research and graduate supervision towards the end of their careers. A balanced faculty age profile thus protects against large oscillations in the scale of graduate programs.

The greying of the academy and the prospect of large numbers of retirements in the 1990s are phenomena well known to most of you so that I will not dwell on them. Let me simply observe that unless we begin the recruitment of replacements now, and find some way to bridge finance them until the prospective retirements occur and they can be incorporated into the funding base, there is likely to be a substantial perturbation in graduate training. It inevitably takes some time for a new faculty member to establish an independent research program and to bring it to a level appropriate for graduate training. With large numbers of new faculty replacing retirees one may anticipate a significant adjustment period during which the numbers of graduate students that can be properly provided for might decline.

The Level of Research Funding

In laboratory based disciplines the scale of graduate training will at some point be determined by the level of operating funds available to the faculty supervisors of graduate students. This is

especially true at the most advanced levels of graduate training where the student is pursuing a line of research which cannot simply be piggybacked on the specific project for which a supervisor has been able to acquire funding. Time does not permit me to describe in detail the current problems with research funding. Suffice it to say that reports from the granting councils make it abundantly clear that many worthy research proposal from existing researchers cannot be funded. In fact the presidents of two of the councils have been prompted to caution universities against using lack of success in obtaining research grants as an indicator of inadequate performance.

New patterns of research support will inevitably influence the scale or pattern of graduate training. The introduction of the matching grant scheme for funding the national granting councils with its accompanying constraints on the base budgets of the councils has clearly had an effect on their general granting programs and hence on research and graduate training in the universities. The growing interest on the part of governments in targeting research support to specific fields or in using new vehicles for sponsoring university based research (e.g. networks of centres of excellence) may very well result in the rapid formation and deformation of research programs and groups with little thought given to the effects of such transformations on graduate training.

Equipment

In my informal soundings among my colleagues in science and engineering on the factors limiting expansion in the supply of graduate students, I was struck by how often lack of up-to-date equipment was cited as of key importance. There appeared to be two aspects to the problem. On the quantitative side several faculty members indicated that their ability to accommodate graduate trainees was limited by the fact that the current use of their existing equipment was stretched to its maximum so that there was no room for additional graduate student users. On the qualitative side, many faculty members indicated that their own work as well as the opportunities for graduate training is constrained both as to the type of graduate training and its level of sophistication because of the lack of state-of-the-art equipment, especially large expensive installations.

Retrenchment in the support of the research infrastructure in universities has of course had its effects in relation to research equipment. Not only are universities less able to contribute to the acquisition of major items of shared equipment they are also less able to provide the technical staff required for ongoing maintenance of research equipment thereby imposing on researchers the necessity of spending relatively more of their operating grants on equipment maintenance.

Research Infrastructure

In addition to support for research equipment and its maintenance the infrastructure for research in universities includes laboratory space, library resources and computer services.

As far as space is concerned many of the faculty respondents to my man-in-the-street interviews indicated that they would rank space limitation below stipends, equipment and operating grants in the hierarchy of factors limiting the expansion of the numbers of graduate students. Not unexpectedly when one poses the same questions to department heads or deans, space limitation takes on a higher level of significance because they are concerned not only with existing faculty but also with providing for the needs of new faculty members or for major expansion of existing programs. In any event it is obvious that at some point further expansion of research and graduate training will depend on a mix of new space construction and retrofitting of existing space.

The state of university libraries has become symbolic of the chronic underfunding of universities. Severe cutbacks in acquisitions and in library services inevitably place constraints on research productivity and graduate training. The introduction of library automation, database networks and modern communications technology have ameliorated the deleterious effects to some extent but restoration to a level approaching the optimum is far beyond the financial capacity of

most Canadian universities.

The increasing importance of computers in virtually all facets of science and engineering is undeniable and the pace of developments in computerization is likely to continue accelerating. By and large Canadian universities have managed, with crucial help from extramural sources, to acquire reasonable levels of computing resource and one would perhaps be justified in suggesting that, except for certain specialized areas, availability of computer services is not a significant factor in graduate training. One may anticipate however that as more and more researchers and research trainees tackle problems which engender a need for large scale computing new demands will emerge.

Future Directions

I have so far examined the capacity of Canadian universities for graduate training from the standpoint of existing programs; that is to say from the premise that our problem is or will be an inadequate supply of the present product of our graduate programs. If that premise is valid then the solution to the problem is obvious. Provide the present system with more money. But if we are also to be concerned about the kind of product then we must consider how the present system of graduate training ought be changed in a qualitative sense.

The present system is based on the premise that graduate training, particularly at the doctoral level, should produce an individual who is capable of independent original research of a kind that one would expect of potential university professors. Since only a minority of such postgraduates become university researchers, it is also held implicitly that such training is also appropriate for those working in other spheres. If we accept the argument that a major expansion of graduate training is necessary to fuel the needs of industrial development then we had better think carefully about what the roles of graduate scientists and engineers in industry are, or are likely to be, and how well our present system of training relates to those roles.

One can posit at least two aspects to the need for more scientists and engineers with advanced training in industry. First, as

technology becomes more complex one requires individuals with advanced training simply to manage certain industrial operations and to adapt new technologies to existing processes. Second, one requires individuals with advanced training who are capable of doing original applied research designed to yield new products or processes. Is the present system of graduate training appropriate for both of these roles or should we be examining a more differentiated approach to advanced training? I am not able with confidence to state that such a differentiated approach is necessary or even desirable but I suspect it could work.

Let me illustrate the differentiated approach with an example from the health sciences. I know there are dangers in extrapolating from one scientific domain to another but the example I shall cite may nonetheless be instructive. As pharmacological research led to the discovery of many new classes of drugs with very potent biological effects it became evident that the health service industry needed to pay increasing attention to how these powerful agents were being dispensed and used. This was especially true in the large specialized centres where patients with increasingly complex diseases were receiving combinations of increasingly complex treatments. The pharmacist with the bachelor's degree was found in general to be insufficiently trained and the Ph.D. research pharmacologist was found to be too specialized and lacking in clinical training to be useful in the hospital setting. A new form of graduate training, which is not centred so heavily on original research, has therefore been developed

for graduate pharmacists leading to a Doctor of Pharmacy degree. Increasing numbers of "D.Pharm's" are now being employed in hospitals as technology consultants who monitor complex drug regimens and the introduction of new products and who accumulate and analyze operational data on drug effects and interactions.

Apart from deciding on what the central focus of graduate training for industry should be, one should also consider both its locus and organization. We have learned enough in recent years from university-industry cooperation in undergraduate training and in research to suggest that we may be able to create increased opportunities for graduate studies of a kind that are most relevant to industry by sharing resources and by providing greater flexibility for part-time study through the development of analogues, at the graduate level, of undergraduate cooperative programs.

Conclusion

Although Canadian universities have been through nearly two decades of retrenchment and are not encouraged by the prospect of further serious financial constraints in the future their latent capacity to increase the numbers of graduate students in science and engineering remains quite substantial. A variety of resource factors will determine both the extent and tempo by which this latent capacity can be exploited and new capacity added. Additional investment in people (graduate students and faculty) and in plant and equipment is crucial since pressures in other spheres will prevent universities from expanding graduate training in science and engineering through internal reallocation of resources at the expense of equally valid endeavors in the social sciences, humanities and the professions.

Harmonization of federal and provincial policies, always elusive, must somehow be achieved in order that increased investment in graduate training in science and engineering by one level of government is not offset by the introduction of countervailing policies by the other level. Universities and industry must build on the growing rapprochement between their respective sphere of activity and together explore the means by which greater flexibility can be introduced in the preparation of highly qualified personnel; and to begin with we need to continue with the difficult task of determining what Canadian industry really needs, wants and is willing to pay for.

The process of building for the future is going to take a good deal of hard slogging. It will not be achieved by empty rhetoric, wishful thinking, "timid hand-wringers or above-the-battle elitists"; but rather by wise, courageous and dedicated people like us.

THE FUTURE SUPPLY OF HIGHLY QUALIFIED ENGINEERS AND SCIENTISTS AND THE ROLE OF NSERC

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Presented at

NSERC Seminar on Canada's Future Requirements for Highly Qualified Scientists and Engineers

Ottawa, May 3, 1989

I. INTRODUCTION

An adequate supply of highly qualified engineers and scientists is important for industrialized countries in order that the industries, universities and governments of these countries can have access to the intellectual talent needed for the promotion of national prosperity and an improved quality of life.

Most countries, including Canada, are now entering a period during which there is some concern that their requirements for highly qualified personnel may exceed the available supply. This situation, if it occurs, will be primarily a consequence of an increasing demand for such persons from the industrial sector, which is subject to intense international competition and a need to use increasingly sophisticated technologies in the development and manufacture of products. It will also be a consequence of demographic forces which may result in smaller numbers of persons obtaining an advanced level education in science and engineering.

The intent of this paper is to examine the current and recent Canadian trends in the supply of, and the demand for, engineers and scientists with postgraduate degrees. An attempt will be made to assess the likely future trends in supply and demand. The disciplines considered in this study are those which fall within the aegis of the Natural Sciences and Engineering Research Council, that is the natural sciences and engineering other than the health sciences. The social sciences are also excluded from this study.

The Natural Sciences and Engineering Research Council is the prime agent of the government of Canada for the promotion and support of research in the universities in the natural sciences and engineering and in the provision of highly qualified personnel in these fields. In partnership with the universities, the private sector, other federal government departments, and provincial governments, NSERC has a profound influence upon the supply of highly qualified scientists and engineers through its programs of grants and scholarships. For this reason, this paper also reviews the various mechanisms which NSERC has in place to promote the education of such persons.

In the light of the supply and demand trends identified in this paper some issues are raised concerning possible new ways of responding to the challenge of ensuring that Canada will have enough highly qualified engineers and scientists during the balance of this century and beyond.

Any opinions expressed in this paper are those of the author and do not necessarily represent the views of the Council.

Some Definitions and Abbreviations

Most of the data used in this paper originates with either Statistics Canada or the Organization for Economic Cooperation and Development (OECD).

OECD data in science and technology generally include both the natural sciences and engineering (NSE) and the social sciences and humanities (SSH). As defined by OECD, NSE includes the health sciences. In this paper, the abbreviations NSE and SSH are used in accordance with OECD definitions.

Statistics Canada classifies its data concerning university enrolments, degrees, faculty members, etc. in certain discipline groups. The groups which are considered in this paper are:

agriculture and biological sciences (ABS)
engineering and applied sciences (EAS)
mathematical and physical sciences (MPS)

The abbreviations given above are frequently used in this paper. It should be noted that the discipline of psychology is included in the social sciences and therefore is not considered in most of the data given in this paper. The EAS group includes, in addition to engineering, the fields of architecture, forestry, and landscape architecture. Generally speaking, engineering accounts for around 90% of any data given for EAS.

II. TRENDS IN THE SUPPLY OF HIGHLY QUALIFIED SCIENTISTS AND ENGINEERS

The Supply Pipeline

Additions to Canada's stock of scientists and engineers come from two sources: Canadian graduates from Canadian and foreign universities, and immigrants from other countries. The latter source has been very important in the past, especially in the 1950s and 1960s. In recent years this source has been of less significance and in the future immigration seems unlikely to be a major, or reliable, source of scientists and engineers, in particular those with research training, in view of the world-wide demand for such persons. For this reason, this paper will concern itself solely with Canadian university graduates. Furthermore, although exact data are not available, it is safe to assume that the numbers of Canadians studying at foreign universities and becoming available for employment in Canada are small in comparison with the numbers of those who emerge from Canadian universities. Therefore, the dominant source of new scientists and engineers is assumed to be Canadians who graduate from Canadian universities and it is this category which will be considered in this paper.

The educational system which produces highly qualified engineers and scientists can be thought of as a pipeline which has its input in the primary schools and whose output emerges from the graduate schools. It takes many years for the commodity to flow through this pipeline, undergoing refinement en route. The process of education of a scientist or engineer with a postgraduate degree may take more than 20 years in total. The pipeline is not only long but it also has many branch-lines leading away in other directions. To place the flows in this pipeline in perspective, for every five hundred children in grade 5 about one will eventually receive a doctoral degree in science or engineering. From the standpoint of those concerned about the supply of highly qualified engineers and scientists the pipeline can be regarded as being leaky. The plugging of some of these leaks in order to reduce wastage of human resources is a matter of importance for the academic, industrial, and government sectors alike.

Because of the time delays characteristic of a pipeline, events which influence the flow at one stage will have an observable effect at a subsequent stage only after a certain lapse of time. It is this lapse of time which makes it difficult to respond to undesirable changes in the output of the pipeline by modifying the flows in, or properties of, the pipeline at an upstream stage.

In this chapter some of the characteristics of the supply pipeline will be examined. Current and recent flow rates (i.e. enrolments) will be reviewed, as will current and recent outputs from the pipeline (i.e. rates of graduation). An attempt will be made to predict the output of the pipeline during the coming few years.

Trends in the Supply of Bachelor's Graduates

The recent decrease in Canada's population in the 18 to 24 year old age group is well known. The nadir is likely to be reached in about 1997 at which time this population will be about 300,000 less than it is at present, and about 800,000

less than it was at the peak in 1981. It is important to note that the population in this age group will increase after 1997 at only a very low rate (assuming that massive immigration does not take place). Thus, even by 2003 the population of 18 to 24 year olds is still likely to be about 250,000 smaller than it is now.

Despite the decreasing population in this age group, it is a fact that the number of full-time university students has been increasing throughout the 1980s. A greater proportion of persons in the 18 to 24 year age group has opted for a university education and more older persons are returning to the universities in order to further their education. There have been some changes in student preference for field of study, however. Figure 1 illustrates the changing share of all full-time bachelor's degree enrolments by Canadian citizens and permanent residents. The downward trend in the proportion of students who choose engineering and applied science (EAS) is noteworthy, as is the upward trend in the percentage of those who choose the agricultural and biological sciences (ABS). The recent steep fall in the proportion of students enrolled in the mathematical and physical sciences (MPS) is striking.

From the standpoint of the need for an adequate supply of engineers and scientists, the trends in the EAS and MPS discipline proportions might be regarded as warning signals. In fact, the signals are more significant than is evident from Figure 1. Not only are the proportions of students in these disciplines diminishing, the absolute numbers are also decreasing at a time when total enrolments are still increasing. Figure 2 provides information about the trends in full-time bachelor's degree enrolments during the 1980s for the 3 groups of science/engineering disciplines.

Table 1 gives data about enrolments of full-time Canadian and permanent resident students at the bachelor's, master's and doctoral levels in the ABS, EAS and MPS discipline groups as well as in certain fields within these groups. From this table it may be seen that, in 1987-88, decreases in enrolments at the undergraduate level occurred in the following fields:

Engineering (all fields combined)
Chemical engineering
Civil engineering
Electrical engineering
Chemistry
Computer science
Geology
Physics

It should be noted that data have been presented only for Canadians and permanent residents because these persons, given current immigration regulations, are those who are potential entrants to the Canadian workforce. It should also be pointed out that, in addition to full-time students, there are large numbers of part-time students at Canadian universities. However, these tend to be enrolled in fields other than science and engineering. Furthermore, they take a longer period to complete their degrees. Consequently, the supply of new scientists and engineers will only be augmented to a small extent from this source.

Table 1

FULL-TIME ENROLMENTS AT CANADIAN UNIVERSITIES
(CANADIAN CITIZENS AND PERMANENT RESIDENTS)

FIELD OF STUDY	1980-81			1981-82			1982-83			1983-84			1984-85			1985-86			1986-87			1987-88		
	B	M	D	B	M	D	B	M	D	B	M	D	B	M	D	B	M	D	B	M	D	B	M	D
Agri. & Bio. Sci	18357	1686	806	17855	1681	555	18370	1743	907	20137	1931	1021	23602	2003	1079	25270	2063	1157	26633	2077	1221	27558	2085	1268
Biology	7851	635	318	7646	644	321	8108	635	345	9183	734	363	11515	763	396	12902	812	409	13822	826	454	14718	821	482
Biochemistry	1392	92	79	1384	84	93	1447	90	98	1698	108	113	2313	160	121	2561	159	146	2899	165	145	3058	168	168
Engg. & App. Sci	31821	1710	535	33445	1771	482	35569	2186	526	35790	3020	660	36070	3127	779	36607	2804	886	36198	2948	1004	35564	2932	1081
Engg. Only	27503	1324	511	29181	1374	457	31305	1784	497	31614	2561	617	32055	2680	722	32645	2406	827	32485	2565	943	31994	2556	1016
Chemical Eng.	2967	141	68	2659	138	66	2883	189	81	2840	287	91	2768	292	105	2716	261	133	2675	263	145	2609	258	160
Civil Eng.	3583	302	77	3489	331	80	3890	451	83	3755	592	113	3679	582	129	3723	501	146	3765	515	163	3702	435	164
Electrical Eng.	4901	330	108	5301	368	108	6374	418	132	6571	605	170	6997	623	203	7284	623	211	7312	668	236	6780	723	236
Mechanical Eng.	4491	144	65	5203	143	59	6171	268	73	6256	467	88	6419	503	98	6503	405	116	6606	424	144	6683	446	182
Math. & Phy. Sci	17014	1359	1021	19595	1570	1054	22837	1736	1168	24515	2129	1280	26300	2314	1396	24856	2251	1504	24179	2290	1620	22891	2316	1673
Chemistry	2476	282	366	2437	340	384	2598	338	428	2749	416	455	3402	441	493	3565	424	535	3814	451	539	3741	459	546
Computer Sci.	4917	262	78	6204	321	78	8302	426	90	9468	497	103	9914	559	134	8725	584	156	7696	575	191	6974	603	211
Geology	2241	273	99	2805	264	114	3208	327	131	3112	462	147	2830	520	159	2309	493	176	1936	447	206	1537	423	215
Physics	1626	281	297	1829	322	299	2011	309	332	2138	378	348	2535	426	348	2644	402	364	2672	432	410	2632	444	418

Source: Statistics Canada B = bachelor M = master D = doctorate

Table 2

DEGREES GRANTED BY CANADIAN UNIVERSITIES
(ALL IMMIGRATION STATUS)

FIELD OF STUDY	1980			1981			1982			1983			1984			1985			1986			1987		
	B	M	D	B	M	D	B	M	D	B	M	D	B	M	D	B	M	D	B	M	D	B	M	D
Agri. & Bio. Sci	5458	617	210	5077	609	220	4915	632	221	4811	624	247	4855	668	237	5130	705	248	5914	803	281	6374	779	343
Biology	2664	223	77	2428	200	70	2237	214	81	2175	215	97	2291	205	81	2485	255	94	3002	303	97	3368	307	129
Biochemistry	385	26	26	346	23	26	425	18	28	451	15	31	420	26	38	477	23	20	595	30	31	666	36	31
Engg. & App. Sci	7247	1109	191	7083	1036	215	7339	1176	183	7734	1285	220	8079	1574	188	8357	1612	278	8271	1716	296	8581	1574	299
Engg. Only	6214	967	179	6173	911	201	6294	1075	175	6689	1184	206	7145	1437	178	7388	1467	261	7291	1572	279	7670	1418	282
Chemical Eng.	582	93	26	665	110	34	667	124	32	759	123	35	746	159	29	798	181	27	701	182	38	739	134	48
Civil Eng.	1567	241	31	1470	224	34	1299	277	31	1168	313	35	1274	366	32	1153	346	49	1048	340	65	1155	327	45
Electrical Eng.	1385	209	62	1427	215	52	1514	242	53	1602	245	50	1769	320	51	1915	337	77	2058	389	82	2202	373	79
Mechanical Eng.	1409	137	22	1368	115	27	1516	152	29	1691	184	32	1827	182	25	1874	258	46	1855	274	36	1915	200	42
Math. & Phy. Sci	4369	767	334	4267	698	341	4867	782	318	5551	833	340	6580	946	373	7571	1031	386	8024	1150	410	7619	1152	477
Chemistry	758	152	145	771	108	135	679	120	120	695	134	139	683	123	152	798	147	138	895	162	153	977	175	178
Computer Sci.	1128	152	25	1218	150	18	1605	186	21	2122	217	20	2707	229	26	3131	254	33	3326	295	27	3002	325	43
Geology	474	136	42	469	128	38	607	146	46	736	133	37	908	190	45	970	215	53	847	211	52	666	216	55
Physics	420	150	63	364	149	78	404	138	68	451	146	82	520	172	85	573	181	100	652	227	89	655	196	101

Source: Statistics Canada B = bachelor M = master D = doctorate

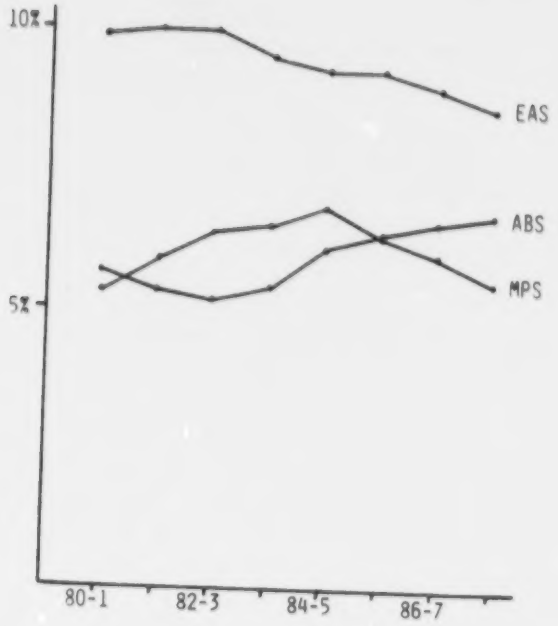

Figure 1. Percentage share of all undergraduate enrolments - Canadians and permanent residents

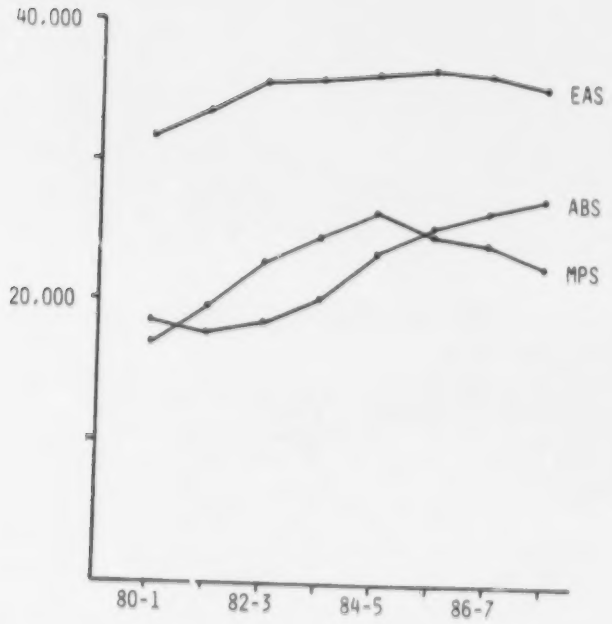

Figure 2. Bachelor's degree enrolments - Canadians and permanent residents

Table 2 gives data concerning the numbers of degrees awarded by Canadian universities at the bachelor's, master's, and doctoral levels in the ABS, EAS and MPS discipline groups as well as in certain fields within these groups. No breakdown of these numbers by immigration status is available. At the bachelor's degree level the proportion of enrolled students who are neither Canadian citizens nor permanent residents is small (in 1987-88: 2.4% in ABS; 6.5% in EAS; 9.5% in MPS). From this table it may be seen that the numbers of bachelor's graduates has generally increased in most fields during the 1980s. However, there was a 10% drop in the number of computer science graduates in 1987 and the number of geology graduates has fallen by over 30% during the past two years. It seems likely, however, that the falling enrolments in many fields, noted above, will translate into reduced numbers of graduates in these fields within the next year or two. On the other hand, the number of bachelor's degree graduates in the life sciences seems certain to increase rapidly. (Parenthetically, it is interesting to note that undergraduate enrolments in psychology bachelor's degree programs have more than doubled between 1980-81 and 1987-88. There were 19,425 Canadians and permanent residents enrolled in full-time bachelor's degree programs in psychology in 1987-88, and 6,133 bachelor's degrees were awarded in psychology in 1987. It is interesting to compare these numbers with other numbers in Tables 1 and 2).

Bachelor's degree graduates form the pool from which the graduate schools receive their intake. The data concerning bachelor's degree enrolments and degrees granted in recent years suggests the following:

> there will be an increasing pool of graduates in the agricultural and biological sciences for at least the next three or four years;
>
> there are indications that the pool of engineering graduates will shrink during the next few years;
>
> the pool of graduates in the mathematical and physical sciences will decrease, immediately in computer science and geology, and possibly in the next year or two in disciplines such as chemistry and physics.

In the longer term, the diminishing university age population may lead to serious problems in connection with the supply of scientists and engineers, as well as for the university system. At the present time, the participation rate (defined to be the ratio of the total number of full-time Canadian and permanent resident students attending Canadian universities divided by the total 18 to 24 year age group population) is about 15.7%. If this participation rate remains constant in the coming decade, the number of full-time students will decrease by about 13% by 1997. Even by the year 2003, the total number of full-time students would be only about 89% of the current number. In order to maintain the number of full-time students at current levels, the participation rate would have to increase to 18.6% in 1997. In other words, the <u>proportion</u> of the population attending universities as full-time students would have to be about 18% larger that it now is.

A recent report from Québec* predicts a drop in the total number of full-time students at Québec universities of about 16% between 1987-88 and 2002-03, even with an assumed increase in the participation rate. If a constant rate is assumed the drop is even greater. All provinces can expect to experience enrolment drops although the decreases will be most significant in Nova Scotia, New Brunswick, Québec and Ontario.

Unless there is a substantial increase in the participation rate in the coming years (which raises questions about the requirements for admission to universities), it seems likely that enrolments will drop in the future with the probable result that the numbers of scientists and engineers receiving bachelor's degrees will diminish.

Trends in the Supply of Master's and Doctoral Graduates

Enrolment data for Canadians and permanent residents in master's and doctoral degree programs are given in Table 1. Some of these data are presented in graphical form in Figure 3 and Figure 4. It is interesting to note, in comparison with Figure 2, that while EAS students significantly outnumber those in ABS and MPS at the undergraduate level, and even at the master's level in recent years, they form the smallest group at the doctoral level. This situation reflects the fact that, in past years, the demand for engineering doctoral graduates was relatively low and that engineering bachelor's and master's graduates generally have more employment options available to them than do the corresponding graduates in the ABS and MPS fields.

The most evident contrast between Figure 2 on the one hand and Figures 3 and 4 on the other is the upward trend in the EAS and MPS curves in the latter as compared with the downward trends for these fields in the former. This is particularly striking in Figure 4. It is clear that Canadian students have increasingly entered doctoral programs during the 1980s. The increase is especially notable in engineering and applied science. At the master's level the increases in enrolments in the first half of the 1980s have transformed into essentially constant enrolments during the second half.

The output of the supply pipeline for master's and doctoral degree recipients during the 1980s is illustrated in Figures 5 and 6, with numerical data being provided in Table 2. As was noted earlier, no breakdown of degree recipients by immigration status is available. Figure 5 and 6 have therefore been prepared on the assumption that the proportion of Canadians and permanent residents among degree recipients corresponds to the proportion among those enrolled for these degrees.

At the master's degree level there is an indication that the annual output may have peaked. The levelling off of enrolments at that level, as shown in Figure 3, is a further sign that the numbers of master's graduates are unlikely to increase during the next few years.

---

* A. Lespérance et J. Lahaye, Les prévisions de l'effectif étudiant universitaire pour investissements: méthodologie générale et prévisions 1987-1988 à 2007-2008. Direction générale de l'enseignement et de la recherche universitaire, Ministère de l'Enseignement supérieur et de la Science, Gouvernement du Québec, 1988.

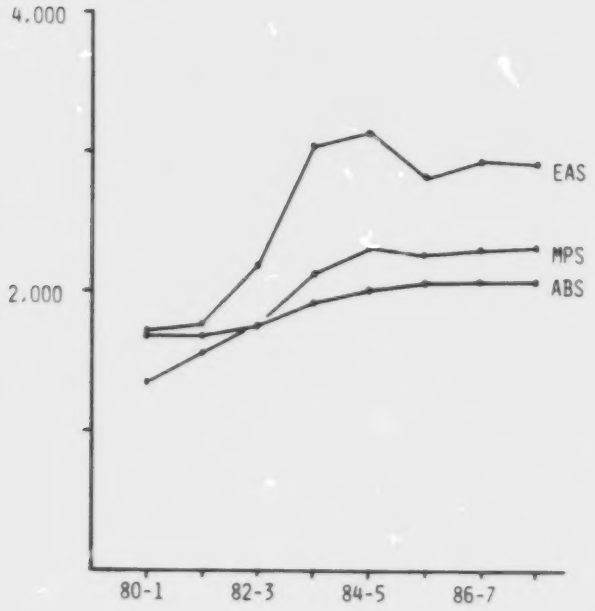

Figure 3. Master's degree enrolments - Canadians and permanent residents

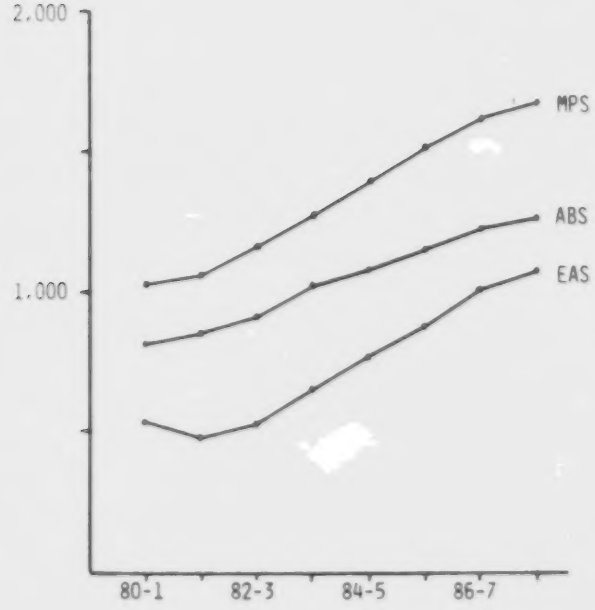

Figure 4. Doctoral degree enrolments - Canadians and permanent residents

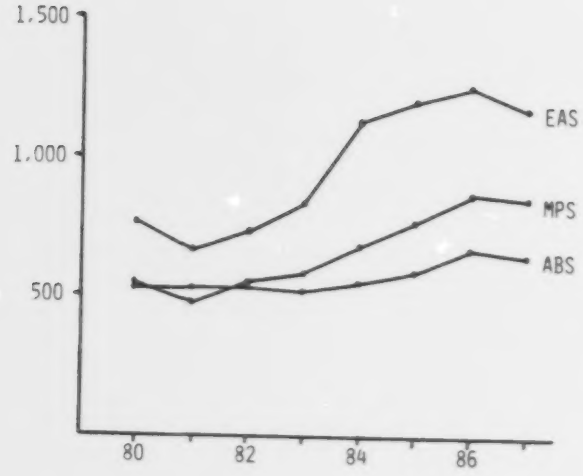

Figure 5. Estimated numbers of master's degree awarded to Canadians and permanent residents

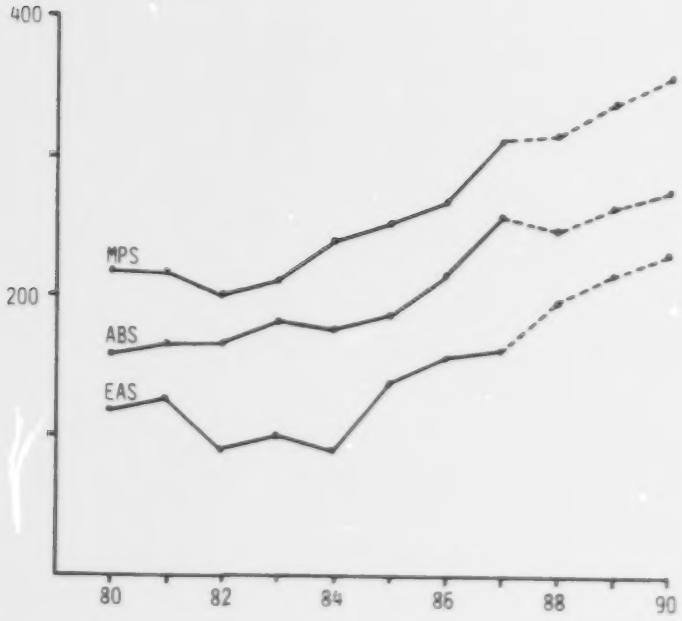

Figure 6. Estimated and predicted numbers of doctoral degrees awarded to Canadians and permanent residents

At the doctoral degree level the annual output has been increasing for several years. It is possible to predict the output for the next 3 years on the basis of doctoral degree enrolments. There is a fairly reliable correlation between the number of graduates in year x with the number of enrolments in year x-3. Using this technique, the number of degree recipients have been predicted up to the year 1990 and these numbers are shown in Figure 6.

In the longer term the prospect of further increases in numbers of doctoral graduates is much less certain. The trends which have been noted at the bachelor's and master's level suggest that, after the delay associated with the pipeline, doctoral enrolments in the EAS and MPS disciplines may level off or decrease. Should this be the case, the numbers of doctoral graduates in the 1990s may also level off or decrease. If this were to come about, this decrease would occur just at the time when demand for such persons is expected to increase significantly (See Section III).

Figure 7 illustrates the estimated numbers of Canadian and permenent resident doctoral graduates for selected disciplines. The contrast in numbers between the disciplines of electrical engineering and computer science on the one hand and those for chemistry, biology and physics on the other hand are noteworthy in view of the particularly strong industrial demand for the former. In fact, when one notes from Figure 6 the relative numbers of EAS graduates compared with those in ABS and MPS, it is interesting to make a comparison with the situation in Japan. In 1984-85 the number of engineering doctoral graduates in that country was 1,291. The total number of doctoral graduates in science and agriculture was 1,421. Thus, engineering graduates numbered 91% of the total for agriculture and science. In Canada, the corresponding percentage in 1987 was 28% (for Canadians and permanent residents).

Summary

In summary, the following points relating to the supply of highly qualified engineers and scientists may be noted:

- there is evidence of a movement away from enrolment by undergraduate students in engineering and in the mathematical and physical sciences as compared with other disciplines.

- trends in undergraduate enrolments and degrees awarded indicate a future levelling off or decrease in the supply of bachelor's degree graduates in many disciplines in engineering and in the mathematical and physical sciences. On the other hand, the number of graduates in the agricultural and biological sciences seems likely to continue to increase for several years.

- the numbers of master's graduates seems to have peaked in most disciplines while enrolments have levelled off. It is likely, therefore, that the numbers of master's graduates will not increase for the next few years.

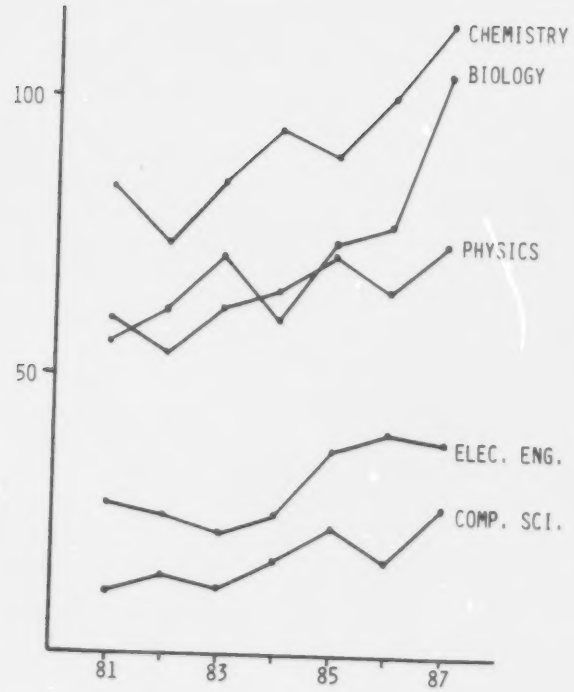

Figure 7. Estimated numbers of doctoral degrees awarded to Canadians and permanent residents - selected fields

- the numbers of doctoral graduates have been increasing in most disciplines in recent years as have enrolments. It is likely that the number of graduates will continue to increase for the next 3 years in most fields. However, trends in enrolments at the bachelor's and master's levels indicate that the numbers of doctoral gradautes will level off, or even decrease, in the 1990s.

- although there has been a steady increase in the number of engineering doctoral graduates, their numbers are still significantly smaller than those for the science disciplines.

- should the university participation rate by young Canadians stabilize at the current level, total undergraduate enrolments will fall during the next ten years. Such an event could have serious adverse effects upon the supply of highly qualified scientists and engineers.

III. TRENDS IN DEMAND FOR HIGHLY QUALIFIED SCIENTISTS AND ENGINEERS

The Industrial Sector

Employment of scientists and engineers in R and D activities by Canadian business enterprises has been growing quite rapidly since 1977. Some data concerning employment of holders of master's and doctoral degrees are given in Table 3. As shown in Figure 8, employment of holders of master's degrees has grown especially rapidly over this period - the total percentage increase has been 149%. However, the growth in employment of doctoral degree holders has also been significant - the total percentage increase being 70%. It should be noted that these data relate only to the NSE disciplines. Data are not available for other disciplines.

Table 3. EMPLOYMENT OF MASTER'S AND DOCTORAL DEGREE HOLDERS IN INDUSTRIAL R AND D (PERSON YEARS)

Year	Master's	Doctorates
1977	1925	1655
1979	2075	1785
1981	2650	2295
1982	3155	2440
1983	3180	2390
1984	3650	2495
1985	3890	2570
1968	4800	2810

Source: Statistics Canada

It is likely that this increase has been brought about by several factors:

- a greater appreciation by employers of the value of the special training received by postgraduate students;
- a trend towards the use of more sophisticated technology in industry;
- the availability of increasing numbers of Canadians holding postgraduate degrees;
- the influence of various schemes designed to increase university - industry interaction and the employment of highly qualified personnel.

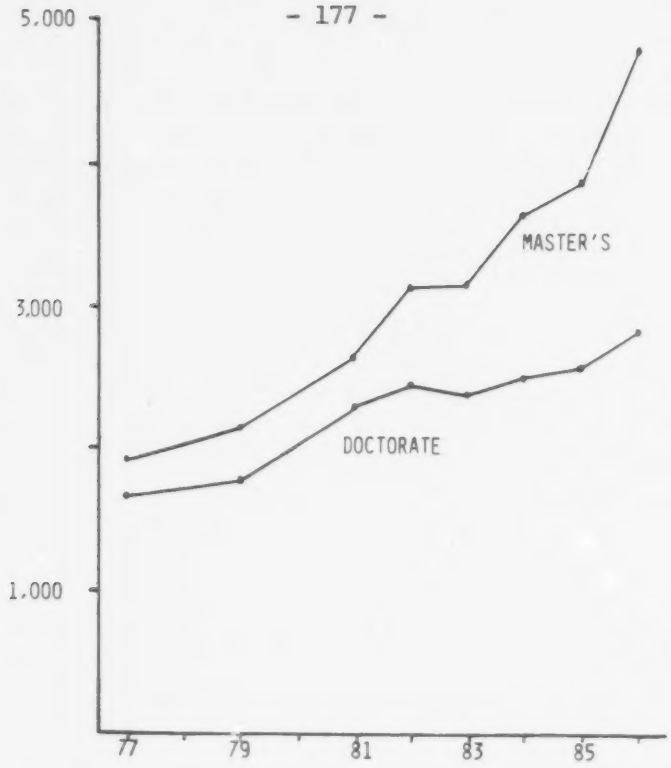

Figure 8. Employment of master's and doctoral degree holders (person years) in the Canadian business enterprise sector

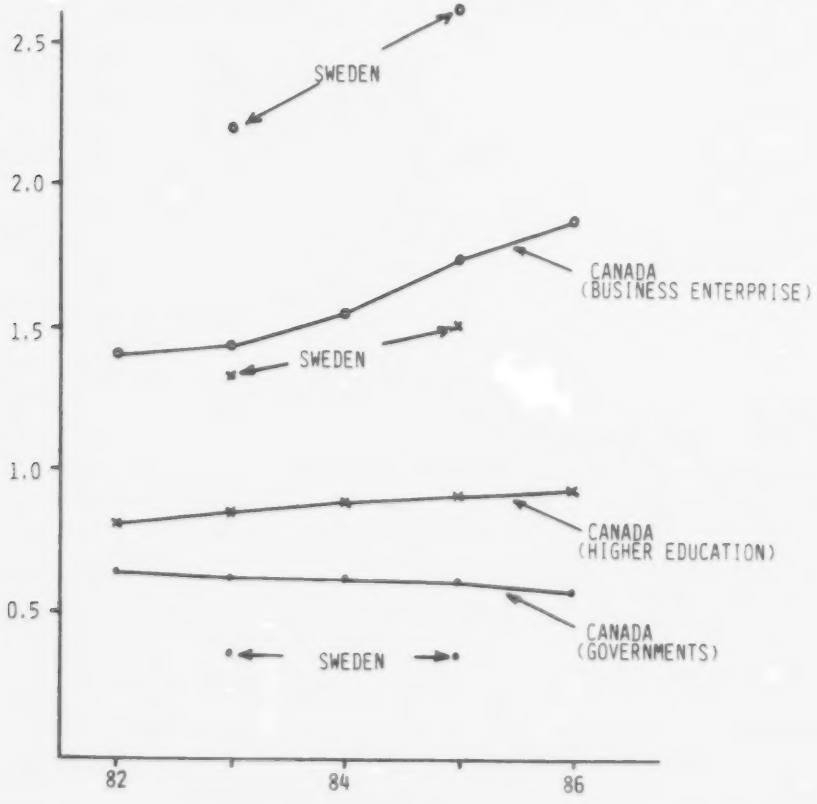

Figure 9. Full-time equivalent research scientists and engineers (NSE only) per 1000 labour force - by employment sector

Certain types of industry are prone to hire employees with postgraduate degrees. The following Statistics Canada data identify those industries which employed the greatest number of doctoral degree holders in 1986:

Engineering and scientific services	380 doctorates
Other chemical products	295 "
Electrical power	225 "
Drugs and medicines	205 "
Telecommunications equipment	200 "
Other electronic equipment	170 "
Refined petroleum and coal products	160 "

These particular industries are such that one would expect them to create employment opportunities for doctoral degree holders in engineering (especially electrical and chemical), chemistry, pharmaceutical science, computer science, and biochemistry, among others.

Comparison of Canadian industrial employment of research scientists and engineers with the corresponding sector in other countries is possible if one utilizes data available from OECD. Table 4 shows the number of full-time equivalent research scientists and engineers employed in business enterprise per 1000 labour force (national total) since 1982 for certain OECD member countries. It should be noted that Canada and Sweden only report persons in the NSE disciplines and so their numbers may be slight underestimates in comparison with those of other countries. The Canadian and Swedish data are illustrated in Figure 9 together with similar information for the higher education and government employment sectors.

Table 4. FULL-TIME EQUIVALENT RESEARCH SCIENTISTS AND ENGINEERS EMPLOYED IN INDUSTRY PER 1000 OF LABOUR FORCE

Year	Canada*	France	Germany	Netherlands	Sweden*	UK	USA
1982	1.40	1.57	-	-	-	-	4.61
1983	1.44	1.61	2.97	1.60	2.21	2.90	4.71
1984	1.56	1.74	-	-	-	-	4.79
1985	1.76	1.84	3.36	1.77	2.63	2.93	4.87
1986	1.89	1.89	-	-	-	3.17	4.98

* NSE only

Source: OECD and Statistics Canada

It is apparent from Table 4 and Figure 9 that employment of research scientists and engineers in Canada has grown most rapidly in the business enterprise sector. Canada has caught up with France and has made some progress in diminishing the lead of some other countries. The comparison with Sweden shown in Figure 9 is especially interesting. It indicates a significant disparity in industrial R and D employment, but also establishes a target for future growth. Had Canada matched Sweden's performance in the business enterprise sector in 1985, Canadian industry would have employed an additional 11,000 scientists and engineers at that time.

What do these figures imply for future industrial demand for research scientists and engineers? It is generally agreed that the prediction of demand for employees in the industrial sector is frequently unreliable. Factors such as business cycles, international competition, oil prices, and emergence of new technologies influence the hiring practices of businesses. Given that trends in these and other factors cannot be foreseen with any certainty it follows that prediction of employment demand is fraught with difficulty.

The available evidence indicates that significant numbers of Canadian companies conducting research and development are currently experiencing problems in recruiting highly qualified research staff and expect these difficulties to worsen in the next five years. A recent report by The Conference Board of Canada* provides information based upon a survey of companies conducted during the summer of 1988. One third of the respondents reported current shortages of qualified R and D personnel and almost one half expected R and D personnel shortages in the next five years.

For the purposes of this paper and of planning for the future it has been thought best to assume continued growth of the Canadian economy in the coming years and, therefore, continuation of the trends shown in Figures 8 and 9. In particular, therefore, it is assumed that demand by the industrial sector for holders of master's and doctoral degrees will continue to grow for the foreseeable future. This demand is unlikely to be uniform for all disciplines. Industrial demand for graduates in some of the life sciences will be low as may be the case for theoretically oriented physicists and mathematicians. In general one can expect relatively high demand for disciplines which are susceptible to application to the real problems associated with product development, manufacturing, and the services sector.

The University Sector

Employment of scientists and engineers in R and D activities by the Canadian higher education sector has grown since 1977, but at a much slower rate than has been the case for the business enterprise sector. Table 5 shows the data for the higher education sector broken down into the NSE and SSH disciplines. It should be noted that Statistics Canada has recently re-calculated all of these figures and those given in Table 5 are somewhat bigger than those previously published by OECD. There are several causes of the increases, but the most significant is the inclusion of over 12,000 full-time equivalent doctoral students. Previously such persons were not included in the figures reported to OECD. This change in methodology is consistent with OECD definitions but, of course, nothing is changed with respect to the actual employment of research scientists and engineers in the higher education sector.

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* J. Warda, R and D outlook 1989: Research and development in the Canadian corporate sector, The Conference Board of Canada, Report 34-88, December 1988.

Table 5. SCIENTISTS AND ENGINEERS (PERSON YEARS) ENGAGED IN R & D IN THE HIGHER EDUCATION SECTOR

Year	NSE	SSH	Total
1977	8280	8780	17060
1978	8560	8550	17110
1979	8520	8850	17370
1980	8850	8950	17800
1981	9160	9080	18240
1982	9780	9360	19140
1983	10490	9570	20060
1984	11080	10050	21130
1985	11610	10170	21780
1986	12070	10540	22610

Source: Statistics Canada

Figure 9 compares the growth of employment for the NSE disciplines alone between the higher education and business enterprise sectors since 1982. The data shown are full time equivalent research scientists and engineers per 1000 national labour force. Because Sweden submits data to OECD for the NSE disciplines only it is possible to compare the Canadian and Swedish figures for the higher education sector as shown in Figure 9. It is evident that there exists a major disparity.

The data contained in Table 5 are not useful as a basis for attempting to predict future employment of research scientists and engineers in the higher education sector because of the inclusion of students, postdoctoral fellows and part-time teachers. For the purposes of this paper attention will be concentrated on one component of this sector: tenure-track or tenured faculty members. In particular, data will be presented for the Agriculture and Biological Sciences, the Engineering and Applied Sciences, and the Mathematical and Physical Sciences. For these disciplines it is now almost a universal requirement that any new appointee to a tenure-track position must hold a doctoral degree. The demand for doctoral graduates to fill these positions forms an important component of the total national demand for doctoral graduates.

Table 6 gives the number of full-time university teachers at Canadian universities for the period 1979-80 to 1985-86 inclusive. It shows that, over this period, the numbers of full-time faculty have increased modestly but that there are differences related to discipline. In the ABS disciplines the increase is only 3.3% whereas in the EAS and MPS disciplines the increases are 11.6% and 10.4% respectively.

An important factor in determining numbers of university faculty is the enrolment of students. Increasing enrolments tend to cause increased numbers of faculty (after a time lag) and decreasing enrolments have a lesser tendency to cause decreased numbers of faculty (because of the tenure system). Figure 10 illustrates how total enrolments of full-time students at all degree levels have

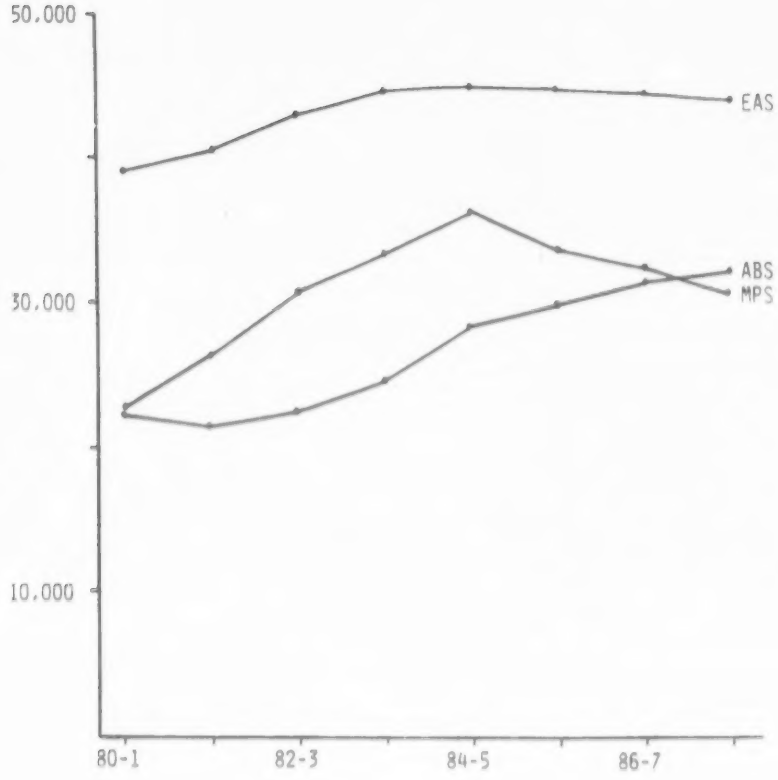

Figure 10. Total enrolments of full-time students by discipline group

Source: Statistics Canada

Table 6. FULL-TIME UNIVERSITY TEACHERS, ALL RANKS, AT CANADIAN UNIVERSITIES

Year	ABS	EAS	MPS
1979-80	2306	2440	4265
1980-81	2372	2454	4276
1981-82	2332	2475	4271
1982-83	2406	2544	4436
1983-84	2326	2626	4480
1984-85	2344	2642	4598
1985-86	2382	2723	4709

Source: Statistics Canada

varied since 1980-81. These data include international as well as Canadian students because all students contribute to the workload of faculty members regardless of their citizenship status. Although not evident from this Figure, ABS enrolments reached a minimum in 1981-82 after several years of decline. The relatively constant number of full-time faculty since 1980 in the ABS disciplines is probably a consequence of the period of declining enrolments. EAS enrolments (which consist mainly of engineering students) increased during the period to 1985-86 but are now showing signs of a decrease. The increased numbers of full-time EAS faculty are a likely result of several years of enrolment increases. The MPS enrolments exhibit a rapid increase until 1984-85 and a rapid decrease since that time. This is largely the consequence of the boom in computer science during the first half of the 80s and its subsequent attenuation in the latter half. The increased number of faculty in MPS is probably linked to this phenomenon.

The future numbers of faculty will obviously depend to some extent upon future student enrolments. What can one expect in this respect? Attention has been drawn in section II of this paper to the existence of recent drops in the numbers of undergraduate students enrolled in several science and engineering disciplines. These drops are reflected in the curves of Figure 10. Reference has also been made to the potential for longer term decreases in enrolments resulting from the continued fall in the population in the 18 to 24 year old age group.

The implications of these trends for the future numbers of full-time faculty at Canadian universities in the sciences and engineering are not certain. However, it seems prudent to assume that, if the discipline shifts referred to above continue for any length of time, there will be a tendency for the numbers of faculty in the EAS and MPS disciplines to stabilize at about the existing numbers. Whether the universities respond to the increasing ABS enrolments by adding more faculty members is a moot point. The universities may, instead, impose enrolment limits and "wait out" the current enrolment boom in anticipation that numbers will drop in the relatively near future.

In summary, it seems prudent to assume that the numbers of full-time faculty in the science and engineering disciplines are unlikely to increase significantly until the late 1990s. At that time, the increasing 18 - 24 year age group population may lead to small enrolment increases in all disciplines. Of course, if efforts by governments to encourage greater numbers of young persons to enter engineering and science programs are successful, enrolments may increase at an earlier date. With this in mind, the assumption of only small increases in faculty numbers is clearly seen to be conservative.

The demand for persons to fill faculty positions is not simply caused by changes in overall numbers of positions. Other factors such as emigration, transfer to other employment sectors, deaths and retirements also create a need for new recruits. With the signing of the Free Trade Agreement the probability of loss of faculty to the United States may increase. It is extremely difficult to quantify this factor, however. One can only state that this is a factor which is likely to increase the demand for new faculty. (It seems unlikely that Canada will be able to attract many new faculty in the science and engineering disciplines from the United States).

Although it is not as up-to-date as one might wish, there exist useful data concerning the age distribution of the faculty of Canadian universities. These data permit the estimation of the future demand for new faculty to replace those who have died or retired. Figure 11 shows the distribution by year of birth for all full-time faculty in the MPS disciplines at the ranks of assistant professor and above. The data for this Figure are for 1985. Corresponding age data are also available for the ABS, EAS and Health Professions fields. Figure 12 presents the same kind of data for the EAS disciplines in a different way. It shows the cumulative percentage of faculty members by year of birth. As is the case in most other industrialized countries, the age distribution of faculty at Canadian universities is far from ideal. Mass hirings by universities in the 1960s and early 1970s were followed by few hirings in the late 1970s and during the 1980s until recently. The result is a faculty population whose median age is increasing, too few young members, and the prospect of very large numbers of retirements beginning in the 1990s and continuing into the first decade of the 21st century.

Ignoring deaths for the moment, Figure 12 indicates that the median age of EAS faculty in 1989 is probably about 49. Roughly 1000 faculty will retire (at age 65) between now and the end of this century. This corresponds to between 35% and 40% of all faculty in this group. This is a simplified analysis and it is necessary to also take into account the mortality rate of the faculty population.

Based upon assumptions of standard mortality rates, and retirements after age 65 being balanced by early retirements, it is possible to estimate the number of vacancies for each year until the end of the century for each of the ABS, EAS and MPS groups of faculty. Table 7 shows the results of such an estimate.

Figure 11. Distribution of faculty in the mathematical and physical sciences, by year of birth, as of 1985

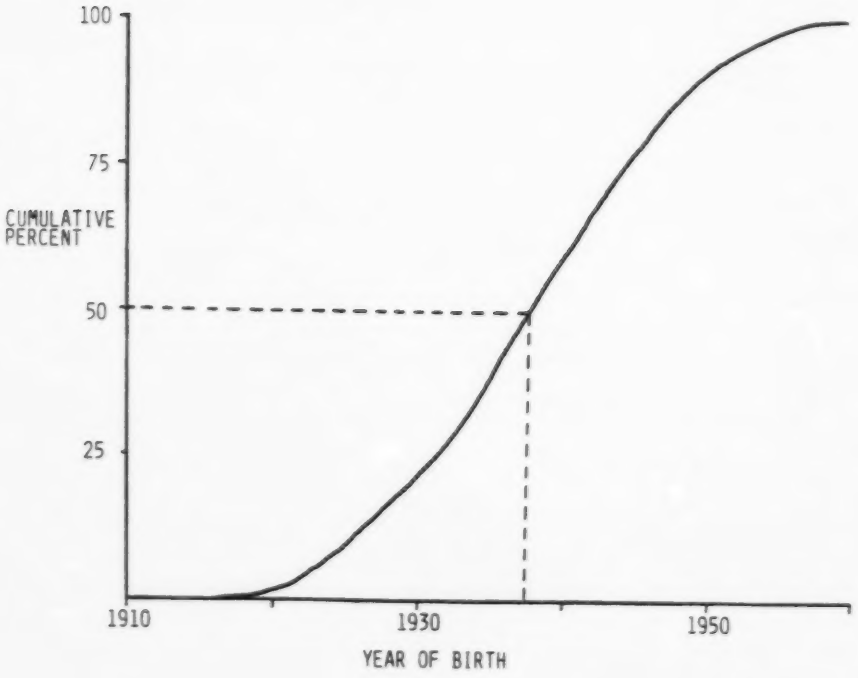

Figure 12. Cumulative distribution of faculty in the engineering and applied sciences, by year of birth, as of 1985

The plotted values are 3-year running averages. While these estimates cannot be treated as precise predictions, the order of magnitude of the estimates and the general trends shown are unlikely to be wrong. It can be concluded that, especially in the MPS and EAS discipline groups, there will be a sharp increase in the number of positions created as a consequence of retirements and deaths between now and the end of the century.

Table 7. ESTIMATED ATTRITION OF FACULTY MEMBERS THROUGH DEATH OR RETIREMENT

Year	ABS	EAS	MPS	Total
1989-90	46	66	82	194
1990-91	50	65	77	192
1991-92	53	65	90	208
1992-93	57	61	92	210
1993-94	64	66	104	234
1994-95	69	73	113	255
1995-96	66	75	119	260
1996-97	67	77	121	265
1997-98	66	80	127	273
1998-99	67	90	141	298
1999-00	71	103	157	331

For the university sector one can summarize the trends which will influence the demand of that sector, in the science and engineering fields, for doctoral degree holders:

- the total number of full-time faculty members is unlikely to increase significantly, assuming that there is no major shift in student enrolments towards the science and engineering disciplines;

- there is likely to be an increase in the number of faculty members leaving to accept positions in the United States;

- there will be a large increase in the number of faculty positions to be filled as a consequence of retirements and deaths.

These three trends combined indicate that demand in the university sector for doctoral graduates in the sciences and engineering disciplines will increase significantly between now and the end of this century.

The Government Sector

Employment of research scientists and engineers in the government sector for the NSE disciplines is given in Table 8. The totals since 1982 are evaluated per 1000 national labour force and are plotted in Figure 9. Comparative figures are given in this Figure for Sweden. It is evident that, in recent years, the total employment has tended to decrease, almost entirely as a result of reduced employment in federal government departments. No breakdown of these data by level of degree held is available.

Table 8. SCIENTISTS AND ENGINEERS (PERSON YEARS) ENGAGED IN R AND D IN GOVERNMENT SECTOR - NSE DISCIPLINES

Year	Fed. Govt.	Prov. Govts.	Prov. Res. Orgs.	Total
1977	5650	840	310	6800
1978	5870	840	300	7010
1979	5780	870	340	6990
1980	5800	820	390	7010
1981	5870	830	400	7100
1982	6300	1100	410	7810
1983	6380	930	410	7720
1984	6480	890	440	7810
1985	6340	970	440	7750
1986	6190	1030	430	7650

Source: Statistics Canada

It seems unlikely, in the federal government sector at least, that there will be any increase in the foreseeable future in the total numbers of research scientists and engineers employed. On the other hand, the age distribution of researchers employed by the federal government seems likely to resemble that of faculty in the university sector. If this is the case, the numbers of persons leaving employment because of death or retirement will be relatively high during the coming years. In some departments, such as defence and agriculture, where current government activities are inappropriate for transfer to the private sector, it seems reasonable to assume that researchers who retire or die will be replaced. However, this may not generally be true for all federal government departments.

In general it seems prudent to assume that future demand from the government sector for research scientists and engineers will not increase over existing levels.

Summary

To sum up this review of trends in demand for highly qualified scientists and engineers, the following points may be noted:

- on the assumption that Canada will continue to experience growth in its economy it is concluded that demand from the business sector for scientists and engineers with postgraduate degrees will continue to grow at a fairly rapid rate. This demand will tend to be concentrated in engineering, many of the mathematical and physical sciences, and some of the life sciences;

- demand for scientists and engineers with doctoral degrees by the university sector will increase substantially over the coming years, mainly as a result of retirements and deaths of current faculty members. This demand will be greatest in the mathematical and physical sciences and in engineering;

- demand for research scientists and engineers by the government sector is unlikely to increase over current levels.

IV. NSERC'S ROLE IN THE PROVISION OF HIGHLY QUALIFIED ENGINEERS AND SCIENTISTS

NSERC Programs and Activities

NSERC administers a range of programs which assist Canadians in obtaining postgraduate degrees in science and engineering. In total about one sixth of NSERC's budget, i.e. about $60 million, will be spent in fiscal year 1989-90 on the direct support of students and others who are furthering their education and research experience. Apart from this direct support of individuals, around $20 million will be spent by faculty members who hold NSERC grants of various types in paying Canadian graduate students as research assistants. In addition, a substantial fraction of the equipment and research facilities used by students in their research has been bought using NSERC grants. It is reasonable to say that, in most science and engineering fields, the vitality of graduate programs and the environment in which students pursue their postgraduate programs are strongly dependant upon the support received from NSERC. It is critically important, therefore, that NSERC's policies and programs be designed so as to promote high quality research and research training in the most effective manner consistent with the general objectives of the federal government.

NSERC's expenditures on scholarships and fellowships can be broken down into three categories as follows:

undergraduate level	$ 6.5 million
postgraduate level	$38.5 million
postdoctoral level	$17.7 million

About 20% of Canadians undertaking graduate studies in science or engineering receive direct support from NSERC in the form of a scholarship. Generally speaking, these are best students who have won their awards in a rigorous national competition. A substantial number of other students receive at least some of their financial support via NSERC-funded research assistantships.

In addition to these various programs which support graduate studies there are several other NSERC activities which are intended to assist in the provision of highly qualified engineers and scientists. These will be described below.

The specific programs offered by NSERC in the research personnel area are as follows:

Undergraduate student research awards - four-month awards which are tenable in either industrial or university research laboratories. They are available to undergraduate engineering and science students. Their objective is to kindle an interest in research and to encourage more students to enter graduate programs. A total of about 2150 students will hold these awards in 1989-90.

Postgraduate scholarships - up to four years of support are available for graduate study at the master's and doctoral level. These awards are normally restricted to tenure at Canadian universities but about 10% are held at foreign universities. A total of about 2500 students will hold these awards in 1989-90.

1967 Science and Engineering Scholarships - these are prestige awards given only to a limited number of the most promising bachelor's degree graduates. They provide up to four years of support for graduate study at the master's and doctoral level. They carry a relatively high stipend and are tenable anywhere in the world. A total of about 180 students will hold these awards in 1989-90.

Postdoctoral Fellowships - up to two years of support are provided for recent doctoral graduates who undertake postdoctoral research. These awards are tenable in Canada or abroad without restriction. A total of about 220 persons will hold these awards in 1989-90.

University Research Fellowships - these awards provide salary support and research grants for five years to promising young faculty members. This program was introduced in 1980 as a response to the problem of providing challenging research career opportunities to young doctoral graduates at a time when few academic positions were available. Since its inception over 500 fellowships have been awarded and over 75% of those completing their five year term have obtained tenure-track appointments at Canadian universities. A total of about 350 persons will hold these awards in 1989-90. No further new awards will be offered after 1989.

Industrial Research Fellowships - these fellowships provide two years of salary support to recent doctoral graduates who undertake an approved program of research or development in a Canadian company. Their objective is to encourage doctoral graduates to consider a career in industrial research and development and to assist Canadian industries in acquiring highly qualified research staff. About 120 persons will hold these fellowships in 1989-90.

Current Research Personnel Program Objectives

In view of the general trends in the supply of and demand for highly qualified engineers and scientists as described in sections II and III of this paper, NSERC's scholarships programs and activities have been planned with certain objectives in mind. These are as follows:

° at least maintain present overall numbers of science and engineering graduate students, and numbers of graduates, while preserving high academic standards;

° encourage more students in fields such as engineering to pursue doctoral studies;

° encourage more students to consider industrial research careers;

° facilitate the academic upgrading of currently-employed engineers and scientists;

° encourage more women to enter engineering and science programs;

° provide additional opportunities for some doctoral graduates to obtain postdoctoral research training;

° actively promote the repatriation of Canadians studying abroad;

° tap foreign sources of research expertise.

Maintenance of present numbers of graduate students is considered as an objective because of signs, described earlier, that enrolments may, in fact, drop in the next few years. It is important therefore, to increase efforts to persuade more qualified students to continue their studies at the postgraduate level. This is being done by means of increased scholarship stipends and an increase in the available number of undergraduate student research awards.

Encouragement of engineering students to pursue doctoral studies is being approached by means of extra increases in scholarship stipends at the doctoral level (applicable to all fields), provision of assistance to the National Committee of Deans of Engineering and Applied Science in their promotion of graduate studies in engineering schools, and in the establishment of a new scholarships selection committee structure which includes a committee for engineering and computer science applicants.

The undergraduate student research awards tenable in industry and the industrial research fellowships both help to make students aware of the challenging R and D careers which are available in industry. The numbers of each of these types of awards have been increased.

On a trial basis, special scholarships are being made available in 1989, to a limited number of engineers and scientists who are currently employed in industry and who wish to return to graduate studies. This initiative caters to persons who decided to return to university too late in the year to apply for a scholarship through NSERC's regular competition, or who were unaware that they could be eligible for NSERC scholarship support.

The demographic trends referred to in section II of this paper indicate that, if drops in science and engineering enrolments are to be prevented, more students will need to be encouraged to choose these study fields. The most promising method for achieving this objective is to persuade more women to enter engineering and the mathematical and physical sciences. NSERC will shortly announce the co-sponsorship with an industrial partner of a "Women in Engineering Chair" at a Canadian university. It is hoped that this action will help to convince more women to study engineering. Some other initiatives are currently under consideration. Current scholarships regulations are being revised to remove any barriers which might hinder women in pursuing graduate studies or postdoctoral research.

Given the anticipated strong demand by Canadian universities for new faculty members in the 1990s and beyond, NSERC has increased the number of its postdoctoral fellowships offered to recent doctoral graduates. Postdoctoral training is considered to be an important feature of the education of a faculty member, especially in the sciences.

There are believed to be up to 1,500 Canadians who are either attending graduate schools or undertaking postdoctoral research in NSERC fields in other countries. These persons form a valuable resource and it is considered important to attempt to encourage as many of them as possible to return to employment in Canada. Lack of awareness of employment opportunities in Canada on the part of the students, and of the existence of these highly qualified Canadians on the part of Canadian employers, hinders the placement of these persons in suitable Canadian jobs. In order to help overcome this problem, NSERC has recently set up a computer-based Register of Canadian Students Abroad. Data about their education, fields of expertise, date of availability, and language competence is currently available on about 500 persons. Employers seeking to fill job vacancies can request a computer search of the data base for persons who meet certain specifications as established by the employer.

NSERC is launching a new program of International Fellowships which is intended to attract promising doctoral graduates from other countries to Canadian universities. The Fellowships will be tenable for up to two years. It is intended to offer about 70 new awards each year with the first awards being taken up in the Fall of 1990. It is the hope of NSERC that this program will strengthen the research training capacity of Canadian universities by bringing in excellent young researchers in relevant fields from other countries. The program will also provide opportunities to obtain access to current research developments in other countries.

Some Questions for Consideration

The various NSERC programs and initiatives described above will assist in the provision of highly qualified engineers and scientists to meet Canada's future needs. But they may not be adequate, by themselves, to avert a future problem. What else could be done?

NSERC has always insisted that holders of its postgraduate scholarships be engaged in full-time study and research. There are sound pedagogical reasons for this policy, but is it unnecessarily restrictive? Given the importance of attracting more women into science and engineering research, might it be helpful, under some circumstances, to award scholarships to students who must spend part of their time on other activities, such as those relating to family responsibilities?

Another long-standing NSERC practice has been to offer its scholarships to the best candidates, regardless of their discipline. This has meant that scholarships have been awarded to students without any thought about the relative need by Canada for graduate degree holders in the various disciplines. It is always very risky to try to predict the future demand for highly qualified persons in specific fields. But is it better to make an informed attempt to do so rather than not to do so at all? For example, would it be sensible to reduce the number of scholarships available to students in some areas and increase the numbers in engineering and computer science?

NSERC data indicate that about 50% of all faculty members who hold NSERC research grants received their first degree outside Canada. The industrial sector also employs many persons who were born outside Canada. Many came to Canadian universities as graduate students and then were permitted to remain as immigrants. Current immigration policy makes it difficult for international students to remain in Canada in order to accept employment. Is it time to reconsider this policy? The international students in science and engineering represent a substantial pool of talented persons. Given the anticipated shortages of highly qualified personnel, would it not be wise to relax current restrictions and allow Canadian employers to recruit some of these students without the necessity to have the students apply for immigrant status from outside Canada?

One factor which can encourage school students to enter science or engineering programs at universities is high quality science teaching in the schools. It has been suggested that the levels of competence and enthusiasm of science teachers could be raised by providing opportunities for them to become associated, during the summer vacation period, with a research group at a university. The opportunity to participate in a research project and work in collaboration with graduate students could be beneficial. The teacher would return to his or her teaching duties with more knowledge about current developments in science, with some first-hand exposure to research, and with a familiarity with the kinds of experiences which await students in universities. To encourage this kind of activity it would be necessary to offer modest scholarships to teachers. The question then arises as to the source of funding for such scholarships. Would it be proper for NSERC to offer awards of this type? Or is this a role more appropriate for provincial governments or the private sector?

CONCLUSIONS

Although it is very difficult to make predictions about the supply of, or demand for, highly qualified scientists and engineers, the evidence presented in this paper suggests that shifts in student field preferences and in the age distribution of the Canadian population may cause the output of bachelor's degree graduates to drop in many fields. While the output of master's and doctoral graduates has been rising in recent years, the trends predicted at the bachelor's degree level, if realised, would give rise to a levelling off or fall in the number of graduates at these levels. This effect would be felt in engineering and the mathematical and physical sciences, but not in the biological sciences.

On the demand side, it has been assumed that the increasing demand from Canadian industry for master's and doctoral graduates in engineering and some sciences will continue in the coming years. The demand from Canadian universities for doctoral graduates to fill academic staff vacancies seems certain to rise significantly during and after the 1990s. These two trends suggest an overall increased demand for master's and doctoral graduates in the 1990s. If realised, this increased demand, coupled with the possible drop in supply, could give rise to significant shortages of highly qualified personnel during the coming years.

The various scholarships and fellowships programs offered by NSERC are important in helping to provide an adequate number of highly qualified scientists and engineers for Canada. These programs are designed to promote student interest in graduate studies and research, to enable the best students to obtain master's and doctoral degrees, and to encourage some doctoral graduates to obtain postdoctoral experience in a university or industrial setting. Other related activities seek to increase the supply of highly qualified engineers and scientists in a variety of ways. This paper has raised the question of whether the current NSERC effort in this area will be adequate if the predicted shortages of personnel are to be anticipated and avoided. Suggestions have been offered concerning some actions which might be taken to enhance the supply of highly qualified scientists and engineers.

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